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THE ROCK OF GIBRALTAR.

1. The rock as seen from the Spanish lines. 2. The city as seen from the jetty. 3. Submerged dikes in front of the rasant batteries.

GIBRALTAR.

THE events of Melilla call the attention of Europe to this important corner of the Mediterranean. It is a question, not only of the contest, several times secular, between the civilization and the fanaticism established at our doors, but also of not allowing the keys of the Mediterranean to fall into too powerful hands.

The English already own Gibraltar. For a long period, in the time of the sail marine, this situation permitted them to bar the passage of a hostile squadron that was unable, without great peril, to maneuver in the strait.

At present, while remaining an impregnable fortress, Gibraltar has no longer very much importance from a strategical point of view. It does not command the passage and would afford little protection to a friendly fleet attacked by superior forces, and, on another hand, its territory is too small to receive an entrenched campaign army. To tell the truth, Gibraltar is no longer any more than a strongly fortified coal depot, and, at the same time, a vast entrepot of smuggling, countenanced by England, to the detriment of Spain.

It may be conceived, however, that this collection of fortifications might become formidable if it could be completed by a few well selected points upon the opposite shore of the strait, and we may be assured that England has thought of this with the tenacity and spirit of pursuance that have always been the basis of her diplomacy. It is for those interested to keep watch.

Gibraltar is of an aspect both very picturesque and very imposing. We give a view of it taken from the Spanish frontier, with which the rock is connected by a narrow, sandy isthmus that constitutes the "neutral zone," in which English and Spaniards are forbidden to erect any building.

This isthmus, which in our engraving seems almost to confound itself with the sea, is sensibly diminishing in width under the erosive action of the currents that lick its two banks. It may be predicted that Gibraltar, in quite a near future, will be detached from the continent, if measures are not taken against the invasion of the water. It is not very probable that such measures will ever be taken by the present possessors of Gibraltar.

The city has a population of 24,000 souls, 6,000 of which are men belonging to the garrison. The majority of the population is Spanish. To this important nucleus are added a number of natives of Morocco, Jews and Mediterraneans of various sources, among whom the English live without intermingling with them.

The climate is quite disagreeable. It is warm and febrific. The screen formed by the mountains arrests the eastern winds which carry persistent fogs only, while at Algesiras, on the other side of the gulf, the sun shines brilliantly.

Aside from the heterogeneous population, the true curiosity of Gibraltar consists in its fortifications. These comprise rasant batteries that extend from the port of commerce to the extreme south. This bastioned line is armed with medium guns and protected against any immediate contact by a mole, flush with the water, that runs parallel with it to a distance of hundreds of yards in front. At certain points the mole is divided into two. There is likewise a series of batteries, armor-clad and casemated, armed with guns of 38 or more tons. These guns are maneuvered by hydraulic apparatus, situated at a great depth below the

surface. At the foot of the promenade called Alameda, a hundred ton gun commands the greater part of the bay.

But the most curious batteries are those that are elevated on three rows of superposed galleries, excavated in the mountain. The highest of those dominates the sea by more than 600 feet.

The value of these batteries is pretty doubtful. It is believed that smoke would render them untenable and that the commotion produced by firing would soon unsettle the rock. What is certain is that they are not used for saluting; but the *Dientes de la Vieja* (teeth of the old woman), as the Spaniards call them, are of a striking effect when they are observed from the foot of the cliff.

Life is not pleasant at Gibraltar. The land and houses are parsimoniously meted out to the inhabitants. The administrative *regime* is that of a state of continuous siege. At sunset the doors are closed, patrols are on the move, and no one has a right to be on the street without authority. However, for a few years past this latter prohibition has not been so absolute, and people are met upon the promenade of Alameda until quite late at night.

One of the peculiarities of Gibraltar is that it is at present the only point in Europe where monkeys are still found in a wild state. Of the same species as their congeners of Morocco, they number at present scarcely a hundred individuals. Very harmless and protected, moreover, by very severe police regulations, they are often seen gamboling in the mountain on fine warm days. They are of the size of a dog, and readily allow themselves to be approached by the curious. It is unnecessary to say that the inhabitants pay no attention to them.—*L'Illustration.*

EGYPTIAN CHRONOLOGY.*

By Samuel Beswick, C.E.

The consecutive life of history is chronology, without which it becomes shadowy and mythical. To be reliable, it must be based on a time-scale, such as is determined by astronomy. It is said that Egypt has never had a chronology, because it is claimed that it never had a definite starting point or a fixed era. But we think this is a mistake; it would be more accurate to say that its chronological system and calendar had been lost and forgotten. The epoch of Menes has ever been at least one fixed starting point and standard era. Modern research will sooner or later discover its lost chronology, and be able to gather up the threads that have been woven into the fabric now known as its lists of dynasties. A technical chronology for Egypt must necessarily have reliable starting points with fixed dates astronomically determined as way-marks; and the more numerous they are, the more certain and reliable the chronology based thereon will become.

The Egyptian calendar was crowded with festivals. Every week, and every day in the week, had its special rites to be either weekly, monthly, half-yearly or yearly observed. There was a perpetual round of religious services, special or general. Some day we may discover the rule for their observance, and among them obtain a clew to the lost chronology of this ancient people. Our present object is to consider one such clew, which has never yet been distinctly understood, known or recognized. The bilingual monument known as the Rosetta stone, which has opened Egyptian literature to the world of letters, several times refers to the "great solemnities" and festivals, called in old Egyptian *hibu set*. One of these, known as the "Thirty-year Cycle," is probably one of the oldest, if not the very oldest, in the calendar, and goes back to the very genesis of Egyptian history. Vestiges of its ancient character can still be found in the Hindoo, Persian, Mohammedan and Grecian modes of reckoning time, and the Moslems have always had a lunar "Thirty-year Cycle," with eleven days added, making $354 \times 30 + 11 = 10631$.

This "Thirty-year Cycle" was not only the most ancient, but had also special privileges attached to its recurrence. It was divided into ten sections or intercalations of three years each, at which a grand festival was held. At the close of every twelve cycles = $12 \times 30 = 360$ years, five years were added in order to adjust it to the Sothic Great Cycle of 1,460 years, or $365 \times 4 = 1460$. These three-year intercalations are kept by the Egyptians as great festivals, called "hibu set," during which it was their custom to erect temples, monuments, monoliths or obelisks and memorials of every kind. They were memorial festivals in an eminent degree, and the ceremonies and festivities were specially devoted to this kind of use. The most eminent were always reserved for the First Intercalation, or third year in a new cycle of thirty years. As it could only occur once in thirty years, the heir-apparent to the throne was usually crowned on this memorial year, the august ceremony of coronation taking place usually on the day of this first of the ten festivals forming the Thirty-year Cycle.

This simple example of an ancient custom in Egypt will throw a flood of light on the subject which, up to present date, has always appeared a mystery; nor has any explanation of the custom, to my knowledge, ever before been published. I allude to the coronation of the heir-apparent at this first festival, and his admission to joint occupancy of the kingly rule, no matter how young the heir-apparent might be, even if he should be comparatively an infant. In a primitive state of society this was a wise and necessary custom; as a precautionary measure it settled the question of succession, and the people were accustomed to the authority and rule of the next Pharaoh before the death of the actual sovereign took place. It also provided for the succession before the infirmities of old age rendered abdication necessary; and finally, it put an end to the strife of rival claimants and incipient revolt, which too often resulted from the sudden death of the king.

Thus Rameses II., oppressor of the Jews, at whose court Moses was trained, was crowned when only a mere youth ten years old. Why at that time? Because the first festival in the "Thirty-year Cycle" then took place. His coronation settled the succession, and all rival claims were at an end. He was a crowned king—a Pharaoh from that time forth and sharer in the administration of the national affairs. The most turbulent times, when revolution succeeded revolution, and Egypt was divided into petty kingdoms, appear to have taken place when a king sat on the throne who had not been crowned beforehand according to custom at the first festival of a "Thirty-year Cycle." Khamuas, eldest son of Rameses the Great, was crowned at one of these festivals according to custom, but afterward died. Menephtah, the fourteenth son, then became heir-apparent and was crowned at the next first festival of the cycle, about seven years before the death of Rameses, his royal father.

Can we find any confirmation of this monumental evidence? Let us see.

It is a matter of indifference whose system of chronology we adopt for the purpose of illustrating our theory of this ancient cycle. We might take any one system of such modern authorities as Maspero, Brugsch, Mariette, or Lepsius, for they all place Seti I. in or about the year 1400 B. C. A few years ago the whole civilized world was startled with the discoveries of the genuine mummies of Seti I., his son Rameses II., and their peers, belonging to the seventeenth, eighteenth, nineteenth, twentieth and twenty-first dynasties, with a few minor royalties and priestly personages of both sexes, with various court functionaries of the two last dynasties. At this time Egyptologists generally fixed the date of Seti I. at about 1400 B. C. We will therefore adopt a medium date of 1392 B. C., and hold the Egyptologists generally responsible for the system of chronology which this date imposes on our illustrations. We do not introduce a system of our own, but take that which our modern, living Egyptologists have placed in our hands.

Accordingly Seti I. would begin his reign in the year 1392 B. C., and the date of his warlike son Rameses' birth would be 1390 B. C. According to the abovenamed cyclar rule and custom, the nearest "Thirty-year Cycle" to the birth date of Rameses would be 1383 B. C., and the first festival would be at the close of the first three years—for there were ten festivals in the series of thirty—or at the date 1383—3=1380. That would be the date of his coronation, according to this system of modern chronology. And since he was born in 1390, he would be ten years of age when crowned at this festival. Rawlinson, in his "Ancient Egypt," says: "At the age of ten or twelve Seti had Rameses crowned as king, and admitted him at first to a nominal and afterward to a real participation in the government. The chronology of the two reigns has been confused by this association. It is uncertain in what year of his reign Seti made Rameses joint ruler." Again, an inscription quoted by Brugsch ("History of Egypt," vol. ii., p. 24) says: "Thou wast raised to be a governor of this land when thou wast a youth and countedst *ten* full years." Let us now step back a little and test the case of his father Seti I.

Seti began to reign in 1392 B. C., and reigned twelve years alone. His royal son Rameses II. was born in 1390, in the second year of Seti's rule. That Seti was in full mature years when he ascended the throne is evident from the fact that after a short reign of Rameses I. he at once took the field against a formidable revolt on his northeastern frontier, consisting of Semitic and Turanian races. In the first year of his reign he began a war with the Shasu. Starting from the fortress of Khetam he mounted his chariot, directed the forces and planned the campaign, entered the Philistine territory, overran Idumea, slaughtered the garrisons of all fortresses, and spread desolation all over the hill country from Egypt to Canaan which he subdued. He has recorded these events in an inscription quoted by Brugsch (*ibid.* p. 13). This prowess shows clearly he had arrived at the age of maturity when crowned. So that the custom of holding the coronation of the heir apparent at the first festival of the "Thirty-year Cycle" could not apply to his case, nor to that of his father Rameses I., the founder of the dynasty. But Seti I. followed the rule and custom. Rameses II. was born two years after his father became king; and although three festivals occurred during the first ten years of his childhood, yet Seti allowed them to pass, and had the coronation of his son, Rameses II, take place at the first festival of the new cycle of thirty years, in 1380 B. C., when the boy was only ten years of age.

The next cycle began in the thirtieth year of Rameses' reign, 1353 B. C., and at that first festival of the cycle he had his son Khamuas crowned in agreement with the custom. But Khamuas died during the cycle, and his place was supplied by Menephtah the fourteenth son of Rameses. Again the custom was followed and Menephtah was crowned at the first festival of the next new thirty-years cycle, in the sixtieth year of Rameses' reign, and six years prior to his death, in 1314 B. C. The date of Menephtah's coronation would be 1320 B. C. So that the thirty-year cycle of 1322 B. C. would fall in his reign, beginning with 1322 B. C., and ending in 1292 B. C. It fact the great Sothic cycle of 1,460 years would end with the coronation of Menephtah. A more notable astronomical incident could not have happened to fix the date of Menephtah's reign, and the closing career of the great Rameses II. Therefore two such thirty-year cycles occurred during the sovereignty of Rameses II. Menephtah reigned about thirteen years and died in 1307 B. C. He was followed by his son Seti II., who was not crowned according to the usual rule, because his father's death occurred about eleven years before the thirty-year cycle closed.

Menephtah's name in Egyptian was Meri-en-Phtah, or "beloved of Phtah," favorite of the Creator. He was also known as Menophres, in whose reign the Sothic period of 1,460 years closed, and a new period began, the date being 1322 B. C. Wilkinson (*An. Egypt.*) says: "The king in whose reign the Sothic period was fixed is said to be Menophres." This test case is rendered the more notable from the fact that the Apis-cycles of twenty-five vague years each began also in the year 1322 B. C., at the same time as the new Sothic period of 1,460 years, and a new series of thirty-year cycles. Lepsius also gives the year 1322 B. C. as the date of Menephtah or Menophres. Here, then, we have a well established astronomical starting point for our illustrations—and a more notable one could not be demanded, on account of its relation to the date of the Exodus.

That a thirty-year cycle was in use at the time stated we have monumental evidence. The tomb of Knumhotep at Benihassan contains a list of twelve festivals, or one whole cycle and two festivals of another, inscribed under the XII dynasty. And Rameses II has recorded a series of these festivals belonging to one and the same cycle, at Silsilis. The first occurred in the thirtieth year of his reign, 1350 B. C., when his eldest son Khamuas was crowned. The second, third, fourth, and fifth festivals are recorded. The last is said to have been in the forty-fifth year of his reign; thus proving that the festivals occurred at intervals of three years. It is further confirmed by an Anastasia papyrus, which refers to a still later festival of the same cycle, dated 26 Mechir, in the fifty-second year of his reign. It must, therefore, have been the eigth festival in the series of ten forming the thirty-years cycle, and three festivals before Rameses' successor, Menephtah, was crowned heir apparent, reigning jointly with his father.

We meet with the hieroglyphic form of the obelisk as early as the V dynasty; but the obelisk set up by Usurtasen I, of the XII dynasty, is the earliest of the kind possessing any considerable importance or grandeur, and has the rare advantage of still remaining on the spot where it was originally set up. It rises sixty-six feet above the plain, is formed of the hardest and most beautiful rose-colored granite, and contains a deeply-cut hieroglyphical legend repeated on its four sides. The inscription says: "The Horus-Sun, the life of those who are born, king of the Upper and Lower lands, Khepr-ka-ra: lord of the double crown, son of the sun-god Ra, Usurtasen: friend of the spirits of On, ever-loving golden Horus, the god Khepr-ka-ra, has executed this work in the *beginning of the Thirty-year Cycle.*" This inscription is invaluable in its relation to the early existence and national use of this cycle as forming a connecting link—the missing link in fact—of the Egyptian Sothic calendar. It was set up by Usurtasen I, of the XII dynasty, at Heliopolis, to commemorate the date of his coronation, which took place, according to ancient custom, on the first festival of the thirty-year cycle. He was then only ten years of age, and in this respect his case is very much like that of Rameses II, who was also crowned when only ten years old, at the first festival of a new cycle. The cycle when Usurtasen was crowned would be the twenty-second in the series from the beginning, in 2782 B. C., and the date would be 2110 B. C. He reigned ten years jointly with his father, and exercised royal authority for about thirty-five years. At the close of the cycle of thirty years, he followed the usual royal custom and ordered the coronation of his son Amenemhat II, who exercised royal authority jointly with his father about four or five years. To commemorate the event, Usurtasen raised a second obelisk in the Fayoum, of a superior character, though less in height. It would be in the twentieth year of his sole reign and the first festival in the new cycle. On the upper portion of the obelisk he is represented as worshiping *twenty* of the principal deities—the twenty he had most favored during his twenty years of sole reign. The date was 2080 B. C.

Amenemhat II took the official name of Nub-kau-ra, and had a sole reign of about thirty-two years. Following the royal custom of his predecessors, at the next first festival of a new thirty-year cycle, he elevated his son Usurtasen to the royal dignity and reigned jointly with him for about six years before entering the eternal abode. This would be the twenty-fourth cycle from the beginning of the second Sothic cycle in 2782 B. C., the date being 2049 B. C. Usurtasen II had the throne name of Sha-khepr-ra, and had a sole reign of thirteen years only. He died before the thirty-years cycle closed; so that his successor would not be crowned, and was not crowned as his predecessors had been. Still earlier evidence is to be found in the period of the VI dynasty. The Sinai rocks contain a monumental inscription of the VI dynasty, recording the first festival of a thirty-year cycle, dated twenty-seventh of the eleventh month and eighteenth year of Pepi I of that dynasty. The date is 3074 B. C., and refers to the thirty-ninth cycle from the beginning of the first Sothic series in 4242 B. C.

The twin obelisks raised at Thebes, and the twin obelisks at Heliopolis raised by Thothmes III, were set up on the first festival of one of these thirty-year cycles; the dates are 1532 and 1502: which again shows how the cycle was used, computed and formed an integral part of the Sothic calendar of 1460 years of 365 days to the year. The addition of five days was called the Epact, and evidently originated in very remote times. A box containing a record of this addition of five days, belonging to the time of Amenophis III, of the XVIII dynasty, is now to be seen at Turin. But there is abundant evidence that this Epact was also officially the close of twelve "Thirty-year Cycles." Wilkinson says: "As the Sothic period was fixed in 1322 B. C., from observations, it is evident that these must have been continued during the time elapsed up to that year, which would throw back the beginning of their observations to a very remote age. The king in whose reign the Sothic period was fixed is said to be Menophres of the XIX dynasty."

Returning to the case of Rameses II, it is interesting to note that within a few months of the joint rule of Seti I and his son Rameses II, falls the date of the famous "tablet stela of 400 years," found at San, the ancient Zoan of the Bible. Of course, this tablet must be regarded as authentic, and set up with royal authority, as the tablet itself declares. The date of this San stela is fourth Mesori, or twenty-eighth July, and the beginning of a joint rule of Seti I and Rameses II. A close inspection will prove that it is a very important stone document. Rameses claims descent from the Hyksos rulers, who held sway in Egypt 400 years previously. This "tablet of 400 years" would begin, therefore, from the joint rule of Seti I and Rameses II in 1380, and would carry us back to $1380 + 400 = 1780$ B. C., or to the king Set Aapehti Nubt, a predecessor of Apophis, under whom Joseph served and directed the counsels of the king. The existence of this tablet implies the existence of a calendar on which it is based.

We have confined our illustrations mainly to the era of Rameses II., because of its intrinsic importance in relation to biblical times and chronology—the times of the oppression and the Exodus; and because it stands about midway between the Christian and Pyramid times, and can be used to help in solving the historic chronology, looking in both directions. Our

* From the "American Journal of Archæology."

main object has been to show the utility of using fixed dates determined astronomically as so many reliable landmarks, and thus reducing conjecture to a minimum.

RECOVERY OF THE LOST CALENDAR.—It would seem that our Egyptologists have been mistaken in assuming that the Egyptians had no chronology nor any fixed era or starting point. We have seen that they had a calendar by which all dates and epochs were measured and located, that the epoch of 4242 B. C. was one of the starting points in their historic chronology, and that t ey divided up the great Sothic cycle of 1460 years into forty-eight lesser cycles of thirty years each, and commonly known as festivals, called "hibu set" or great solemnities. The kings, it is true, dated their annals by their regnal years, and the dates of a king's accession and demise were commonly placed on record by the priests, so that the entire length of his reign could be known, and no special care was taken to distinguish the years of his sole reign from those during which he was associated with his predecessor. Neither as a general rule were contemporary dynasties distinctly marked. But the fact has been forgotten that the dates of the king's accession and death and all other notable events were linked together by being made parts of a "Thirty-year Calendar or Cycle," which stood in successive order in the list of forty-eight cycles forming the great Sothic cycle of 1460 years, of which each king's accession formed one of the notable events in some one of these forty eight cycles of thirty years each. The following chronological synopsis of the calendar—tabulating three entire Sothic cycles of 1460 years each, with the series of forty-eight cycles forming this one grand period—will illustrate this Egyptian system of chronology. The following table begins with the first cycle, and with the first month Thoth, when the Sothic cycle begins.

In this table we have recovered the long-lost Sothic Chronological Calendar by which Egyptian festivals were regulated, numbered and classified, and their chronological place and date in history determined. Henceforth this calendar will form a working scale for future Egyptologists who may feel disposed to use it; as it will materially help to classify the dynasties so as to present them in something like an approximate historic form. The date of Khufu and the pyramid kings of the IV. dynasty will be 3451 B. C. The date of Pepi I. of the VI. dynasty is 3074 B. C.; of Usurtasen I. the date will be 2110 B. C.; the twin obelisks of Thothmes III. at Thebes and Heliopolis will have the dates 1532 and 1502. Rameses II. will be 1380, and Menophres will close the forty-eight cycles in the second Sothic cycle of 1460 years at the date 1322 B. C. Thus we contend the Egyptians did always have a chronology, and counted their number of festivals by classifying them in this series of forty-eight "Thirty-year Cycles" in 1460 years. The starting point and zero of the second series being the epoch 2782 B. C. The famous "tablet of 400 years" found at San, constructed by Rameses II., was based on this thirty year cycle calendar.

I think it not improbable that the restoration of this calendar will do more than any other agency to restore the lost chronology of the Egyptian nation. Out of ten obelisks, four distinctly state that they were erected at the first festival or third year of a thirty years cycle. Such are those of Thothmes III. at Thebes and Heliopolis; Usurtasen's obelisk, the one in New York, and the Campensis at Rome erected by Psammetichus II. These obelisks are really chronological monuments of the existence of this lost Sothic calendar, which appears to have been in popular use in every age back to the time of the building of the Great Pyramid and the establishment of Egyptian empire. Beginning at the early Christian period, we have Theon, the astronomer, who declares that the complete Sothic cycle of 1460 years ended in 139 A. D.; and all along the centuries backward its existence has been acknowledged. It was noticed by Tacitus, Eratosthenes, Berosus, Manetho, Herodotus and others during the five centuries before the Christian era. And we have traced it up from Menophres, Rameses, Usurtasen and Pepi I. to Pyramid times. The early record of Pepi I. can still be seen on the rocks of the Sinaitic peninsula.

The mode of reckoning by this thirty years' calendar was as simple as the modern calendar we use to-day. The cycle was reckoned as the first, second,

THE ROCK OF GIBRALTAR.

1. Promenade and battery of Alameda. 2. The subterranean batteries.

TABULAR VIEW OF THE SOTHIC CYCLE OF 1460 YEARS.

First Sothic Cycle: 4242 B. C.—2782 B. C.

	4242 B. C.		B. C.
I	4211·583	XXV	3481·583
II	4181·167	XXVI	3451·167
III	4150·750	XXVII	3420·750
IV	4120·334	XXVIII	3390·334
V	4089·917	XXIX	3359·917
VI	4059·504	XXX	3329·504
VII	4029·084	XXXI	3299·084
VIII	3998·667	XXXII	3268·667
IX	3968·250	XXXIII	3238·250
X	3937·834	XXXIV	3207·834
XI	3907·427	XXXV	3177·427
XII	3877·000	XXXVI	3147·000
XIII	3846·583	XXXVII	3116·583
XIV	3816·167	XXXVIII	3086·167
XV	3785·750	XXXIX	3055·750
XVI	3755·334	XL	3025·334
XVII	3724·917	XLI	2994·917
XVIII	3694·504	XLII	2964·504
XIX	3664·084	XLIII	2934 084
XX	3633·667	XLIV	2903·667
XXI	3603·250	XLV	2873·250
XXII	3572·834	XLVI	2842·834
XXIII	3542·427	XLVII	2812·427
XXIV	3512·000	XLVIII	2782·000

Second Sothic Cycle: 2782 B. C.—1322 B. C.

	2782 B. C.		B. C.
I	2751·583	XXV	2021·583
II	2721·167	XXVI	1991 167
III	2690·750	XXVII	1960·750
IV	2660·334	XXVIII	1930·334
V	2629·917	XXIX	1899·917
VI	2599·504	XXX	1869 504
VII	2569·084	XXXI	1839·084
VIII	2538·667	XXXII	1808·667
IX	2508·250	XXXIII	1778·250
X	2477·834	XXXIV	1747·834
XI	2447.427	XXXV	1717·427
XII	2417·000	XXXVI	1687·000
XIII	2386·583	XXXVII	1656·583
XIV	2356·167	XXXVIII	1626·167
XV	2325·750	XXXIX	1595·750
XVI	2295·334	XL	1565·334
XVII	2264·917	XLI	1534·917
XVIII	2234·544	XLII	1504·504
XIX	2204·084	XLIII	1474·084
XX	2173·667	XLIV	1443·667
XXI	2143·250	XLV	1413·250
XXII	2112·834	XLVI	1382·834
XXIII	2082·427	XLVII	1352·427
XXIV	2052·000	XLVIII	1322·000

Third Sothic Cycle: 1322 B. C.—139 A. D.

	1322 B. C.		B. C.
I	1291·583	XXV	561·583
II	1261·167	XXVI	531·167
III	1230·750	XXVII	500·750
IV	1200·334	XXVIII	470·334
V	1169·917	XXIX	439·917
VI	1139·500	XXX	409·500
VII	1109·084	XXXI	379·084
VIII	1078·667	XXXII	348·667
IX	1048·250	XXXIII	318·250
X	1017·834	XXXIV	287·834
XI	987·417	XXXV	257·417
XII	957·000	XXXVI	227·000
XIII	926·583	XXXVII	196·583
XIV	896 166	XXXVIII	166·167
XV	865·750	XXXIX	135·750
XVI	835·334	XL	105·334
XVII	804·917	XLI	74·917
XVIII	774·500	XLII	44·500
XIX	744·084	XLIII	14·084
XX	718·667	XLIV	17·334 A. D.
XXI	683·250	XLV	47·750
XXII	652·834	XLVI	78·167
XXIII	622·417	XLVII	108·583
XXIV	592·000	XLVIII	139·000

third, fourth, and so on successively to the forty-eighth cycle which ended the series, and completed the Sothic period of 1460 years. The cycle of Pepi I. would be called the thirty-ninth thirty year cycle in the series, having the date 3074 B. C. The cycle of Usurtasen's obelisk would be the twenty-second, having the date 2110 B. C. The cycles of Thothmes III's obelisks would be the forty-first and forty-second, having the dates 1532 and 1502 B. C. The coronation of Rameses II. in 1380 B. C. would begin the forty-sixth cycle in the series. While the commencement of the Apis periods of twenty-five vague years would close the second Sothic period of 1460 years in the year 1322 B. C., during the reign of the Exodus king Menephtah or Menophres. In this way the whole Sothic calendar was chronologically connected in one unbroken chain from 4242 B. C. to 139 A. D.

By this means the great Sothic cycle was simplified and divided into convenient festival periods of three years, ten of which made what was called a "Thirty years Cycle." These festival periods were subservient to the popular taste for short recurrent festivities, while they enabled the scientist and astronomer to correct any error that may have crept into the vague or civil year.

RED SHALES AS CONNECTED WITH THE GENESIS OF BITUMEN IN CALIFORNIA.*

By A. S. COOPER, C.E.

SHALES were and are deposited in still and salt water. The iron contained in these waters and organic remains, both animal and vegetable, and the other materials constituting the shales were deposited contemporaneously.

If the iron was the peroxide of iron (Fe_2O_3, ferric oxide), by contact with organic remains it was deoxidized and reduced to a protoxide (Fe O, ferrous oxide), by the absorption of one equivalent of its oxygen, when the peroxide was reduced to a protoxide; or if the iron was the protoxide, carbonic acid, produced by the decomposition of organic matter, then united with the protoxide, forming carbonate of iron ($FeCO_3$). The carbonate of iron imparts a bluish or greenish color to the deposit.

* This article is in part a continuation of the subject in discussed the Supplement of Sept. 3, 1892.

Sulphide of iron (Fe S_2, ferric sulphide) is frequently formed and deposited instead of carbonate of iron. The sulphates of lime (Ca O, SO_3) and of magnesia (Mg O SO_3 + 7 HO), and other sulphates which exist in sea water, when subjected to the action of decaying organic matter out of contact with air, are deoxidized and converted into soluble sulphides, from which sulphureted hydrogen gas is set free by the carbonic acid gas produced by the decomposition of organic matter. Sulphureted hydrogen converts the soluble compounds of iron into sulphide of iron. The color of pyrites is brass yellow.

When unaltered by oxidation the carbonate of iron, with varying amounts of lime, clay or sand, is dark grayish blue or green, or even white in color.

When unaltered by oxidation the sulphide of iron is brassy yellow in color.

From the preceding explanation, it is safe to say that, at the time of their deposition, these shales were not red; and as long as they are not submitted to oxidizing influences they will not become red.

When the carbonate of iron is exposed to the oxidation of the air it forms limonite (hydrous ferric oxide), which is usually of a brownish yellow or brownish red color. These iron ores are found in all stages of transformation. On the outcrop they are limonite; under dense cover, carbonate; while going from the outcrop inward the limonite constantly decreases in proportion to the carbonate. In the alteration of the compact carbonate the line of chemical change and color is usually very sharply defined, and the limonite covering can often be entirely removed from the inclosed core of carbonate by a blow with the hammer, the limonite covering preventing the carbonate core from being oxidized by the air. In shales charged with gray carbonates of iron, the following reaction takes place: the carbonic acid is released and part of its oxygen oxidizes the iron.

Gray shales, containing finely divided pyrites or bisulphide of iron, are converted by heat into bright reds, the sulphur being released, leaving the shales charged with red oxide.

The color of burnt ferruginous shale is entirely due to the amount of iron present. Gray shales, containing less than 1 or 1½ per cent. of iron, change by heat to various shades of cream color or buff; while those containing 2 to 10 or 12 per cent. of iron produce by heat bright red bodies. The depth of the color depends merely on the amount of iron present, the buff shades graduating into the deeper shades of red.

A group of stratified rocks usually consists of various species arranged in alternating beds, a series of beds of many hundreds or even thousands of feet in thickness containing strata of shale, limestone or sandstone.

Some strata are porous or seamed and easily penetrated by fluids, serving as conduits and reservoirs for fluids. Some strata are nearly impervious to fluids, while others are practically so, frequently serving as incasements for the conduits and reservoirs formed in and by the porous and seamed strata. All stratified beds have been originally deposited in a horizontal position, or approximately so. While the beds were in the horizontality of their deposition and incased by impervious strata, there was little or no circulation of fluids within their porous and seamed strata. When they were tilted and inclined to the horizon at angles varying from the perpendicular to nearly absolute horizontality and their porous and seamed strata exposed to the entrance of fluids by denudation, fracture or otherwise, and an exit for the fluid was supplied or produced at a lower level than the place of its entrance, the circulation of fluids commenced, slowly at first, and gradually increasing as the inclination and exposure of the different strata became greater. The subterranean courses of the circulating fluids are complex and anfractuous.

Water supplied by the rainfall of the region enters at the outcrop of the porous and seamed strata. If the porous and seamed strata are incased in impervious strata, the greater the depth to which the strata extend from the place of entrance of the water, the greater the pressure will become. In some instances this pressure will be very great, forcing the water into comparatively impenetrable rocks.

The water, percolating and circulating through the porous and seamed strata, by its solvent action accumulates mineral ingredients. These waters, saturated with minerals, coming in contact with other minerals existing in the shales, by chemical reactions produce heat. This heat contracts and fractures the shale, permitting a freer circulation of water. This chemical heat distills petroleum from carbonaceous shales and oxidizes the carbonate and sulphide of iron, producing the red color of the shales; and the water of different temperatures, charged with mineral ingredients, will frequently rise by hydrostatic pressure through fissures, faults, etc., to the surface of the earth, forming mineral springs. These mineral springs are often accompanied by bitumen. An imaginary section is shown in Fig. 1, illustrating the above description.

But very few fossils exist in these red pyrogenous shales, as they have been obliterated by the solvent action of hot water or by chemicals held in solution by the circulating waters; or, if moulds or casts of their external or internal forms existed, they have disappeared from the same causes or have been crushed and distorted beyond recognition.

RED SHALES IN CALIFORNIA.

Red shales in California are the effects of chemical heat. Strata which have been more or less altered by the action of heat, emanating in the strata from chemical reactions, consist of burnt shale, porcelain jasper, earth, slag, or coke, and white shale.

Burnt shale. Its color is usually red, sometimes gray, yellow or brown and graduating from cream color to brilliant red. It is clay or shale, burnt but not so much changed as to form a porcelaneous mass.

Porcelain jasper. It is shale or common clay, changed into a kind of porcelain by the action of heat. It is dark red, yellow, or striped yellow and red.

Earth slag or coke. This is clay or shale converted into a kind of slag or coke. It is black, brownish or reddish and it has occasionally a tempered steel tarnish. Sometimes it shows iridescent colors. It is vesicular, usually amorphous, but occasionally possessing the prismatic form of artificial coke.

White shale. Evidently occasioned by steam and water and then heat. It easily becomes pulverulent and does not consolidate by the action of the weather. When dry it is an incoherent powder, so that when walked over, people will sink into it to quite a depth.

PHENOMENA.

They are discovered by their bright colors, by the heat of the earth in their vicinity, sometimes by smoke. Sulphurous and other vapors frequently occur. These in their course upward incrust the fissures of rocks and even the surface of the ground. Mineral springs, hot or cold, issue from the ground in their vicinity. The earth is charged with salts and minerals occasioned by the percolation and evaporation of these mineral waters. Shales, through the joints of which these mineral waters have flowed, have become impregnated with salts and the salts subsequently to the flow have been vitrified by heat. They are further known by the issuance of warm or cold natural hydrocarbon gas, by seepages of bitumen in their neighborhood, by fissures, rifts, joints, and porous sand rocks filled with asphalt, and by the almost total absence of fossils in the burnt shale, porcelainite and coke, which have been obliterated by hot water and heat. Serpentine cups filled with a pigment made from these bright shales are dug from the graves of the aborigines.

About thirteen miles east of Santa Barbara an excavation was made on the bluff of the ocean for the roadbed of the Southern Pacific Railroad; and the gray shale, charged with chemical substances, from the excavation, was thrown over the bluff, forming a conical shaped pile, composed of pieces of shale containing from one to eight cubic inches. Water could easily penetrate the broken shale, and air could freely circulate through the mass. When the winter rains fell upon this pile of shale, chemical action commenced, producing sufficient heat to vitrify and weld the shale together. A large part of the shale was burned to a red porcelainite and the remainder was colored a buff shade, graduating into the deeper shades of red. (The chemical reactions producing this heat are under examination.) Above the railroad track the face of the shale bluff has been cut off to the angle of repose by the railroad company. This smooth surface is a good place to observe the action of chemical heat and attending phenomena.

A sectional view is shown in Fig. 2. A, burnt shale of a bright brick red color; B B B, smoky shales containing carbonaceous and bituminous substances; F, greasy looking place, highly charged with mineral ingredients. Some parts of the shales in this place become deliquescent when exposed to the air; C C C, shale containing carbonaceous matter; D D, seams filled with evaporated salts through which mineral waters formerly ascended; E E, shales, the joints of

FIG. 1

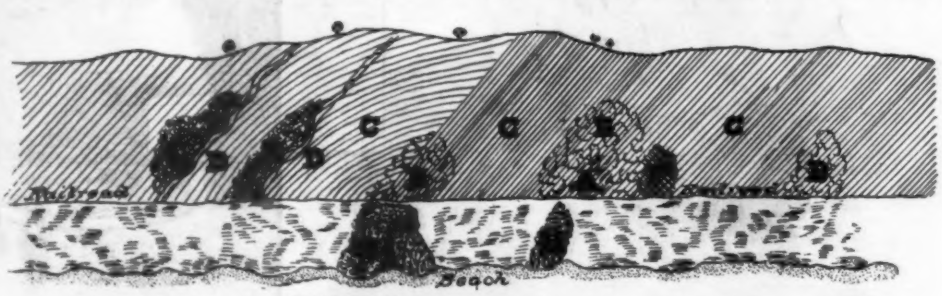


FIG. 2

which are filled with indurated bitumen; H H H, fragmental shale, excavated in the construction of the railroad and burnt and welded together by chemical heat after excavation.

LA PATERA MINE.

La Patera mine lies nine miles west of the city of Santa Barbara. Its relation with a lake and the ocean is shown in Fig. 3. The lake contains several acres. Along the periphery of the lake the stratification of the shale dips toward the lake, at an angle varying from 30° to 40°. The composition and the arrangement of the component parts of the soil are the same on the islands as upon the mainland. The shale must have existed at a level shown by the dotted lines in Fig. 4, and subsided after the deposition of the soil; otherwise the soil could not have been deposited on the islands in a manner similar to that of the mainland. This subsidence was probably occasioned by the contraction of the underlying shale produced by chemical heat. If the basin of this lake had been formed by erosion of the land by sea or surface water, the shale would have been squarely cut off and not contorted so as to dip toward the lake. At A, Figs. 3 and 4, heat has vitrified the salts which had been deposited in the joints of the shales by the flow of mineral waters. In the excavations at the mine at the depth of one hundred feet a temperature of 105° Fah. is generated in the shales by chemical heat. Circumjacent to the lake are fissures filled with hard asphalt, through which comminuted shale and mineral water are disseminated. Off the shore petroleum rises from submarine springs, covering a large surface of the ocean with a thin film of iridescent oil. Its odor can be detected at a long distance. Ledges of hard asphalt exist in the ocean below high tide, running nearly parallel with the shore. Surface wells show the existence of water highly charged with mineral substances in which petroleum is dissolved. So far no potable water has been found near the mine.

Six miles west of Santa Barbara City, on the Calera rancho and on the ocean shore, an area of ten acres has subsided some twenty-five feet. Of this subsidence three feet have occurred within the last four years. This subsidence has occurred through the contraction of the shale. The surface of the subsidence is rifted and seamed; and from these rifts and seams sulphurous and other vapors ascend. The ground is hot. The bluff is composed of burnt shales showing tints from a cream color to brilliant red. Water containing salts seeps from the base of the bluff. Shales with carbonaceous material, shales saturated with bitumen and smoky shales surround the hot places. Near the hot places heavy petroleum oils ooze through the shales. To the eastward and westward thick petroleum tars ascend through the cracks and joints of the shale. Some of the seams of shales containing a small proportion of bitumen have hardened to such an extent that they resemble dark flint and will cut glass.

There is a number of places in California, near these red shales, from which natural gas issues. Some are hot, showing that they are formed at high temperatures.

It may not be out of place to mention in this connection the occurrences of red shale in other parts of the world in which bituminous deposits are known to exist.

RED SHALES IN THE ISLAND OF TRINIDAD.

The formation of the island of Trinidad consists of clay, loose sands, shales, limestones, calcareous sandstones, indurated clays, porcelainites of brilliant red colors; with pitch deposits and lignite here and there. The only substances containing sufficient carbon and hydrogen for the formation of asphalt and likely to be inclosed in strata are vegetable and animal remains. The former are particularly abundant at La Brea, where most of the asphaltic beds have been originally carbonaceous or lignitic shales. Mineral springs abound throughout the island. In a series of loose sands, clay and shales lies Pitch Lake, seemingly occupying a depression in the strata. To the southward of the lake the shore is made up of bold cliffs, the strata of which consist of indurated clays of brilliant red and yellow colors. They present also thick veins of porcelain jasper. Strata of loosely coherent sandstone also abound, some of which are impregnated with bitumen. Rounded pebbles of pitch and porcelain jasper form a beach at the foot of the cliffs. A species of coke is occasionally observed along the shores with porous structure and the prismatic form of the artificial product, but, of course, much denser, on account of the large proportion of earth. Near the lake is a red, yellowish substance, semi-baked, evidencing a considerable degree of heat which attended its formation. Part of the impurities in the Trinidad asphalt consists of comminuted red clays or shales, with some sand. It is evidently not adventitious at the surface, but must have been thoroughly incorporated and brought up from the depths with the bitumen, judging from the constant amount, dissemination and character in all parts of the deposit. Water, containing all the mineral ingredients of strong thermal water, is found in the Trinidad asphalt. The presence of borates, iodides and so many forms of sulphur compounds and other characteristics shows that the water must be of the same origin as that of many thermal springs. This water, in all unaltered pitch, shows that the formation of the pitch and water must have been simultaneous and cannot be considered adventitious. It would be impossible for water in any adventitious way to become so intimately mixed with the bitumen as to form practically an emulsion. Near the center of the lake is a body of pitch softer, blacker and newer than that of the remainder of the lake. Gas constantly issues from the cracks in the bitumen. These phenomena show that asphalt is being distilled at the present time. The porcelainites and red shales must have been formed by heat created in the strata themselves, as these shales are burned uniformly, in one place showing a much greater degree of heat than another. They are probably formed in the same manner as similar rocks in California. The depression in which Pitch Lake lies was probably made by the subsidence of the surface of the earth, caused by the heat contracting the underlying shale, like the sinking of the earth on the La Calera rancho and at the La Patera mine in California.

The presence of scattered carbonaceous and lignitic matter in the shales, the uniformity of the diffusion of heat shown throughout the surrounding strata, the character of the fine shale evenly disseminated through the pitch, the presence of mineral waters sealed in the asphalt, the presence of immense amounts of bituminous distillates, porous strata to permit the entrance of water, and the conditions existing in these deposits analogous to those in California, all tend to prove the action of chemical heat and the creation of red shales by this heat.

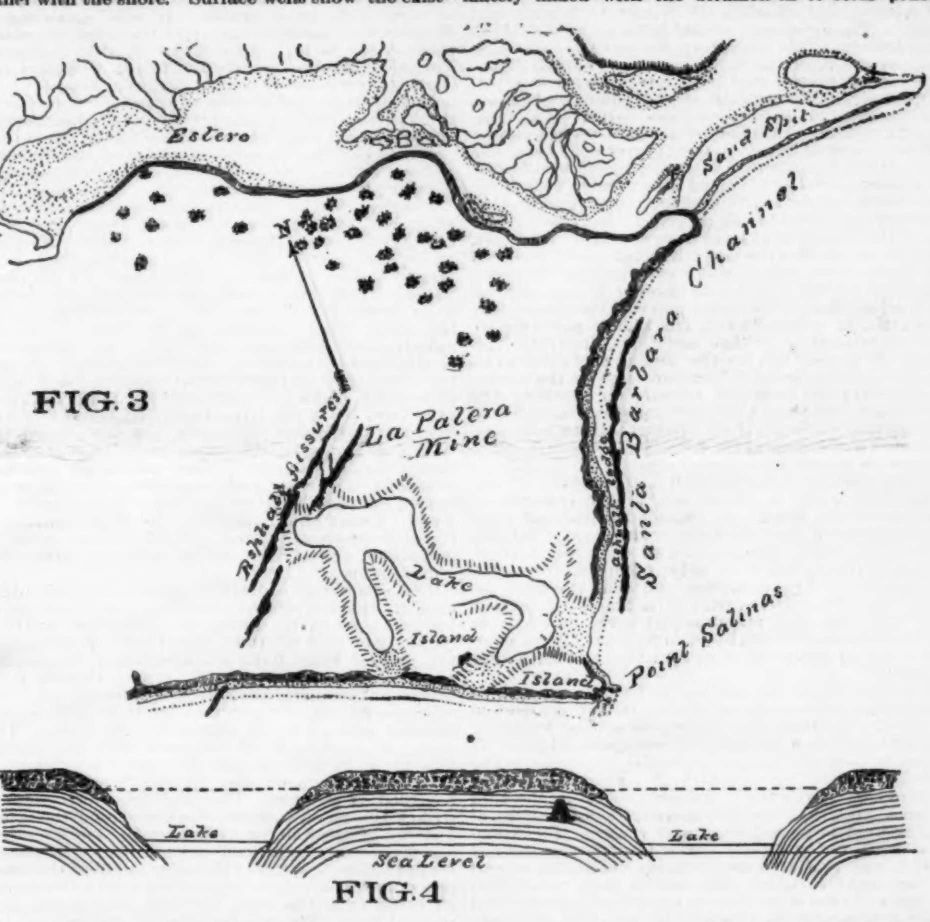


FIG. 3

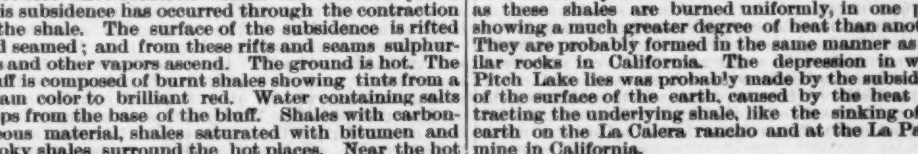


FIG. 4

RED SHALES IN PENNSYLVANIA.

In Pennsylvania the red shales are not confined to any geological horizon. In some places they are several thousand feet thick and in other places they are but a few feet thick. They occur above, between and below the oil sands. In some instances they are found directly underneath the oil sands, at other times immediately above, while at other times they do not join the sands. Below the oil sands red shales are nearly universal. They are variable and local, occupying intervals in one well which are filled with gray shales in another well only a short distance from it. Notwithstanding the large number of wells drilled in the oil districts, nearly all have at some level penetrated red shales and frequently have passed through several bodies of red shales. Sometimes they are rather soft, pure argillaceous shale, at others they are arenaceous shale. The red color has been imparted to these shales subsequent to their deposition. And, judging from the position of these red shales in regard to porous strata carrying circulating waters, and the mineral constituents and high temperature of springs in their neighborhood, and the quantity of petroleum distillates in their vicinity, they in all probability are colored through chemical heat, in the same way as similarly colored shales in California.

RED SHALES IN OHIO.

The most conspicuous red formation in Ohio is the Bedford shale, beneath the Berea grit. It is of varying thickness. The upper part is generally of a marked red color, while the lower part is a dark, bluish gray. These colored shales are very variable in their relative thickness, sometimes one or the other filling the entire interval between the Berea grit above and the black shales below; sometimes that interval being equally divided between them, and sometimes one or the other greatly predominating while both are present. In the red shales fossils are noticeably absent. The bluish parts of the Bedford shale are often filled with petroleum. There is a line of oil springs which mark the base of the Bedford shale all along its line of outcrop. These shales are heavily charged with pyrites of iron. The outcrop of these shales often shows the presence of chemical heat, these chemical fires lasting for months and years. The bright red banks of Paint and Vermilion Creeks owe their origin to these fires. The brilliant red shale was used as a pigment by the aborigines. The red shales in Ohio have not the same geological horizon as the red shales of Pennsylvania.

The presence of porous strata admitting water to these shales, the absence of fossils, probably eradicated by the solvent power of hot water, the mineral springs issuing from this stratum and the petroleum distillates flowing from the same, all tend to show that the red color was created by chemical heat.

THE DEAD SEA.

Great quantities of asphaltum appear floating on the surface of the sea. On the southwest bank are hot springs. The neighborhood, in addition to sulphur, bitumen and hot springs, abounds with lava, pumice stone and other volcanic productions. Smoke is said to ascend occasionally from the lake and new fissures to take place in its bank. The water of the sea is highly impregnated with salts.

Numerous other places could be mentioned where hot waters accompany the flow of bitumen and evidences of volcanic action abound.

INDIANA GAS FIELD.

In some parts of the Indiana gas field the temperature of the gas in some wells is 10° F. lower than in others, some wells recording 60° F. and others 50° F. This temperature and difference of temperature are doubtless due to chemical reactions. As long as abnormal conditions of temperature can be detected at these depths in which gas was formed, the production of natural gas is still in progress.

There are mountains of these red, pyrogenous shales in California scattered throughout the coast range of mountains. Large bodies are situated in the range of mountains between the Seini and Santa Clara valley, on the north coast of the Santa Barbara channel, in the mountain range south of the Santa Maria valley, in the mountain range between the Los Alamos and Santa Ynez valleys and in numerous other places. At the Buenavista deposit, near Bakersfield, are shales, coked by these fires and breaking in prismatic forms, showing beautiful iridescent colors. Bituminous deposits may occur without the red shales being visible; but unquestionably they exist near by, as they are the stills in which petroleum is distilled from carbonaceous matter in the shales by chemical heat, water and different chemicals being present.

Santa Barbara, California, November 24, 1893.

[Continued from SUPPLEMENT, No. 938, page 14996.]

THE MOON'S FACE—A STUDY OF THE ORIGIN OF ITS FEATURES.

By G. K. GILBERT.

Tidal Theory.—Of other theories, a few are somewhat related to the volcanic. It is hardly profitable to discuss the suggestion that the greater walls were formed about the vortices of a primeval liquid moon,* nor the suggestion, albeit advanced independently by several authors, that the vast circling cliffs of the moon are remnants of Cyclopean bubbles that have burst.† But an ingenious tidal theory, which appears to have sprung up independently in France, Germany, and England,‡ merits careful examination. It postulates a time when the moon was liquid, with the exception of a thin crust. The moon then rotated more rapidly than now, and great tides, excited by the earth's attraction, racked and cracked its crust and here and there squeezed out a portion of the liquid nucleus, which flowed back again when the tidal wave had passed; but congelation caught the flood at its edges, so as to mark its limit by a solid ridge. By each successive tide the operation was repeated, with the result that the wall was given a circular form and was gradually built up. The process was finally closed by the congelation of lava in the orifice, and while congelation was in progress, the last feeble eruption sometimes produced a central hill.

In certain respects this theory is well founded. It is true that the earth is able to produce far greater tides on the moon than the moon produces on the earth, and if we may accept the conclusion of G. H. Darwin

* Rozet: Memoire sur la Selenologie. Comptes Rendus, vol. 22 (1846), p. 470.

† Robert Hooke: Micrographia (1667) [not seen]. Jules Bergeron: L'Astronomie (1882), p. 346; (1888), p 112. A. St. Clair Humphreys: Jour. Brit. Astr. Ass., Dec., 1891, p. 132.

‡ Faye: Rev. Scientifique, 27 (1881), p. 130. H. Ebert: Ann. Physik und Chemie, vol. 41 (1890), p. 351. J. B. Hannay: Nature, vol. 47 (1892), p. 7.

that the moon is retreating from the earth,* then the reciprocal tides of moon and earth were greater at an earlier date than they are now. That a circular ridge may be built up by the alternate extrusion and retraction of a suitable substance through an orifice has been demonstrated by Ebert, who devised apparatus and conducted a series of experiments. The crater rims he achieved sloped regularly outward and were steep and rudely terraced inward, thus reproducing the more important features of the lunar rims, with the exception of the wreath, and by special manipulation he was able to approach the characters of the wreath.

In other respects the theory finds less support. At the time of formation of the larger craters the crust must have been thick and strong to sustain the weight of their rims. It could not then or afterward have been divided by a close plexus of cracks, but such a plexus seems necessary under the theory to account for the multitude of small craters which overlie the large. Again, it is pertinent to inquire whether the crustal strains engendered by great tides in a liquid nucleus would find relief in the postulated manner. If the crust were divided by fissures, would not the tensile strains wrought by the crest of the tidal wave cause the fissures to gape, instead of forcing out the liquid through apertures here and there? Or, if there were no fissures, would not the strains suffice to produce them? The postulated normal stresses are measured by lava columns from 5,000 to 15,000 feet in height, and the tangential strains resulting from the greater of these stresses would rend a crust of granite 100 miles thick.† Yet, again, there are numerous craters of small or medium size occupying slopes of the greater crater rims, and the initiation of these by tidal process seems impossible. Whatever lava escaped from an orifice on a slope would flow down the slope instead of being drawn back.

Snow Theory.—Another theory assumes that the moon is covered with snow or ice. The site of each crater was occupied by a pool of water which by heat from below was vaporized. The vapor was quickly converted into snow, part of which fell back in the pool to be vaporized again, and all of which was eventually accumulated in an annular ridge.‡

There is some reason to question the existence of water and ice on the moon's surface, but as this subject will presently be considered in another connection, the point will be waived here and attention restricted to questions of form and relation. If the rim were built up by the quiet fall of an infinitude of ice particles or snow flakes, its configuration should be smooth and regular instead of exhibiting the rugosity actually observed. The postulated heat of the central area might render the inner slope steep and even produce the inner cliff and terraces, but the theory affords no explanation of the wreath nor of the central hill. It fails likewise to account for the small craters formed on the rims and slopes of the larger, for the bottoms of these are far above the assumed rock plain of the moon through which the theory supposes the internal heat to have been communicated.§

Meteoric Theories.—All other theories which I have been able to discover appeal in one way or another to the collision of other bodies with the moon's surface, and for want of a better term I shall call them meteoric. If a pebble be dropped into a pool of pasty mud, if a rain drop fall upon the slimy surface of a sea marsh when the tide is low, or if any projectile be made to strike any plastic body with suitable velocity, the scar produced by the impact has the form of a crater. This crater has a raised rim, suggestive of the wreath of the lunar craters. With proper adjustment of material, size of projectile, and velocity of impact, such a crater scar may be made to have a central hill. Thus scars of impact may simulate in many ways the scars of the moon's face, and a number of theories have accordingly been broached which agree in regarding the craters as due to the bombardment of the moon by projectiles coming from without. As the present study is primarily physiographic, these similitudes of form have been considered with great care, and it is my belief that all features of the typical lunar crater and of its varieties may be explained as the result of impact. The special considerations presently to be adduced are along this line.

Long ago it was suggested that the projectiles might have been fired from terrestrial volcanoes, but the speed actually acquired by the ejecta of volcanoes falls so far short of that necessary to carry them beyond the sphere of the earth's attraction that this view is no longer entertained. All other suggestions have regarded the material as cosmic. Every shooting star records by its brief coruscation the collision with our atmosphere of a particle of star dust; and though the number of these which can be seen by an observer in one night is not great, it has been computed that no less than 400,000,000 are captured by the earth in the course of twenty-four hours. So minute are they in general that their ashes do not contribute to the earth's surface an appreciable layer of dust; but a few have such size that they are not completely consumed in traversing the atmosphere and fall to the earth as aerolites weighing grains, ounces, pounds, even tons. For the most part they strike the atmosphere with a velocity far higher than could be induced by the earth's attraction, and we must believe that they are speeding through space in all directions in numbers that defy the imagination. They must collide with all planetary bodies in numbers depending chiefly on the area of surface exposed, and the moon, of course, receives its share.‖

* Article "Tides" in Encycl. Britannica, vol. 23, p. 378.

† The computation on which this statement is based assumes 2·75 as the density of the lunar lava and 11,000 pounds per square inch as the tensile strength of granite. It assumes also that all parts of a vertical section of crust are subjected to the same strain, but any tidal deformation of the crust would make the distribution of strain unequal.

‡ John Ericsson: Nature, vol. 34 (1886), p. 248. S. E. Peal: Nature, vol. 35 (1886), p. 100; English Mechanic and World of Science, vol. 47 (1888), p. 477.

§ These statements may do injustice to Peal's version of the theory, which has been given to the world only in abstract. I have not seen his fuller exposition in a pamphlet privately printed in India with an edition of 100.

‖ I have discovered no published statement of meteoric theories more than twenty years old, but the idea is older and various obscure allusions indicate that it was earlier in print. Proctor makes a meteoric suggestion in 1873 (The Moon, p. 346), and advocates it in 1878 (Belgravia, vol. 36, p. 153). A meteoric theory is said to be contained in *Die Physiognomie des Mondes*, by "Asterios," Nordlingen, 1879. A. Meydenbauer advances another in Sirius, for February, 1882, and he includes bodies other than cosmic.

As the moon either is without atmosphere or has one of extreme tenuity, the mechanical effect of this bombardment may be important, for the average velocity of the meteors is from 50 to 100 times as great as that with which the swiftest ball leaves the cannon, and the energy of a projectile is measured by the square of its velocity. Nevertheless, it is incredible that even the largest meteors of which we have direct knowledge should produce scars comparable in magnitude with even the smallest of the visible lunar craters. Recognizing this difficulty, advocates of meteoric theories have assumed that at some earlier period the meteors encountered by our solar system were of greater size than now, and as no evidence has been found that the earth was subjected to a similar attack, there is assigned to the lunar bombardment an epoch more remote than all the periods of geologic history, any similar scars produced on the earth having been obliterated by the processes which continually reconstruct and remodel its surface.

Another difficulty has been found in imagining a condition of lunar surface which should admit at the same time of plastic moulding and of the preservation of the resulting forms. The steep inner slopes of lunar craters are, in places, from 15,000 to 20,000 feet in height; their stability in the presence of even the feeble gravitational force at the moon's surface demonstrates great strength of material, and the mind does not readily associate great strength with plasticity. To avoid this difficulty it has been assumed by some students that the moon's surface was soft when the craters were made; but it seems to me that this assumption does not really escape the difficulty, for it will not do to postulate a degree of softness incompatible with the survival of lofty cliffs. To my mind it appears that the difficulty is only imaginary and not real. Rigidity and plasticity are not absolute terms, but relative, and all solids are in fact both rigid and plastic. The apparent contrast between the two properties belongs to the laboratory and to those phenomena of nature involving small masses and small forces. When great masses and great forces are involved, as, for example, in the making of continents and mountain chains, the distinction loses value. The phenomena of mountain structure demonstrate that under sufficient strains great bodies of rock both bend and flow. If the lunar craters were produced by collision, the masses of matter involved were greater than those of terrestrial mountain ranges and the concentration of energy was correspondingly great. Moreover, a portion of this energy may have been converted into heat, with the result that the parts affected were rendered less rigid or even molten, and it even appears necessary to assume a result of this sort in order to account for the level surfaces of the inner plane of the craters. My friend, Mr. R. S. Woodward, has kindly made for me some computations which serve to illustrate this point. If a body fall to the moon's surface from an infinite distance, being influenced only by the attractive power of the moon, its velocity on reaching the surface will be one and one-half miles per second; and the equivalent energy, if all converted into heat and all stored in the mass of the falling body, would suffice to raise its temperature, supposing it to consist of ordinary volcanic rock, through 3,500 degrees of the Fahrenheit scale. In other words, the quantity of heat developed would be greater by one-half than that necessary to fuse the body. The average velocity of shooting stars is estimated at 45 miles per second, or thirty times that of a body falling freely to the moon, and it is easy to understand that the heat developed by the sudden arrest of a fragment of rock traveling with such speed might serve not only to melt the fragment itself, but also to liquefy a considerable tract of the rock mass by which its motion was arrested.

It is convenient to mention in this place a special phase of the meteoric theory which, though not devised to avoid this difficulty, nevertheless does avoid it. Meydenbauer, as a corollary of certain conclusions in regard to meteoric matter, holds that the surface of the moon is clothed with a mantle of cosmic dust, a deep layer of loose particles everywhere concealing the solid nucleus, and that the fall thereon of aggregates of similar dust produced the lunar craters. By experiment with various finely divided substances he has in this way produced small craters simulating several of the lunar varieties. His results show raised rims analogous to the lunar wreath, central hills, and arched inner plains, such as characterize a few of the lunar craters. His published results do not include level inner plains, nor the association of inner plains with central hills; but, on the other hand, he does not extend this process to the largest craters and the maria. For them he suggests the collision of solid stars of sulphur or phosphorus, originally moons of the earth's system, and he recognizes fusion as one of the results of their collision.*

The third difficulty is found in the relation of the volume of the rim to the capacity of the hole. If the collision produced no condensation of the lunar tract affected (and condensation would be anticipated only on the hypothesis of cosmic dust), we should naturally expect to find in the rim the entire volume of matter displaced in the formation of the hollow plus the volume of the moonlet; but this relation does not appear to obtain. The impression derived from telescopic observation and the inspection of photographs is that the rims of some craters are commensurate with the hollows, while the rims of others are not, and this impression is confirmed by computations based on the measurement of shadows. Ebert has compiled the available published data and computed the ratio of rim content to cavity content for ninety-two craters, ranging in diameter from 8 to nearly 100 miles.† In twenty-eight instances he finds the rim content the greater; in the remaining sixty-four instances he finds it the smaller; and in about fifteen instances the rim volume is but a small fraction of the content of the cavity. He finds further that the rim is relatively small or the cavity relatively large in the case of the larger craters. Though the imperfection of the data gives a large probable error to the determinations, there can be no question of the general fact that in many instances the rims of large craters are quite inadequate to fill the cavities they surround. This is an important fact, but it is not necessarily inimical to the impact theory. In the course of a series of laboratory experiments, in which craters were produced by throwing projectiles of various plastic materials against targets of similar materials, it was occasionally found that the rim when pared away would not fill the hollow, and the cause of this result was discovered. When target and projectile were of uniform consistency throughout, there was no defect of rim; but when the general mass of the target was softer than the portion at the surface, the uplift consequent on the production of the hollow was only partly localized about its periphery, the remaining part being widely distributed through flow of the softer material below. It is possible, therefore, to interpret the quantitative relations discovered on the moon in terms of local physical condition without rejecting the impact theory.

* A. Meydenbauer: Sirius, February, 1882.

† H. Ebert: Ueber die Ringgebirge des Mondes. Sitzungsberichten d. Physik.-med. Societat. Erlangen, p. 171. Munich, 1890.

A fourth difficulty is connected with the circular contours of the craters. If a ball of mud be allowed to fall vertically upon a horizontal surface of the same material, the resulting crater is circular; but if instead it be thrown obliquely, the resulting crater has an oval contour. Except for irregularities which may be counted as details of form, some of the lunar craters are as nearly circular as can be determined by measurement; others are slightly elliptic; a few only are notably elongate. It is inferred that the predominant direction of the incident bodies supposed to have formed them was vertical to the lunar surface or nearly so; but it can be shown from simple geometric considerations that the predominant angle of incidence of swift-moving meteoric bodies approaching from all directions would be 45 degrees, and the scars produced by such collisions would be predominantly oval instead of predominantly circular. So far as my reading has extended I have discovered but one suggestion for the obviation of this difficulty, and that was applied only to very small lunar craters. It was suggested by Proctor that immediately after the shock of collision there might be an elastic return to a circular form.* The idea requires for its realization a high tensile elasticity, such as we do not know in any rocks, but only in certain substances of organic origin, and it thus fails to receive support from the phenomena of our terrestrial experience. There has occurred to me an entirely different mode of escaping the difficulty, and as this is my personal contribution to the subject, it will be set forth somewhat fully.

Moonlet Theory.—Besides the nomadic and apparently individual meteors of space, there are certain groups symmetrically arranged and moving in a systematic and orderly way. One of these groups is arranged in the form of a ring and encircles the planet Saturn. This ring is broad and thin, and all parts of it lie nearly in one plane. The meteors which constitute it are so numerous that portions of the ring appear continuous and solid. They are too small to be individually perceived, but there can be little question that they all travel about the planet in a system of parallel orbits and with correspondingly adjusted velocities. It is my hypothesis that before our moon came into existence the earth was surrounded by a ring similar to the Saturnian ring; that the small bodies constituting this ring afterward gradually coalesced, gathering first around a large number of nuclei, and finally all uniting in a single sphere, the moon. Under this hypothesis the lunar craters are the scars produced by the collision of those minor aggregations, or moonlets, which last surrendered their individuality.

This change of conception yields a material difference in the law of the directions in which minor bodies approach the moon, the difference depending on the fact that all the minor bodies colliding with the greater body have initial orbits lying approximately in the same plane. To render this clear it is necessary to amplify the statement already made with reference to the predominant angle at which cosmic meteors encounter the surface of the moon. Their velocities are so high, as compared with the acceleration due to lunar attraction, that their courses in the vicinity of the moon may, without sensible error, be regarded as straight. The angle at which each one strikes the moon's surface depends upon the nearest distance of its produced orbit from the moon's center, and is entirely independent of the direction from which it approaches. We may therefore simplify the discussion of incidence angles by assuming that the meteors all come from the same direction and move along parallel lines. The number of meteorites being indefinitely large and their distribution entirely independent of the moon, we may for this purpose conceive them as an evenly distributed rain, of which the moon receives a certain portion. This simplified conception is embodied in the diagram, Fig. 10. The angle of inci-

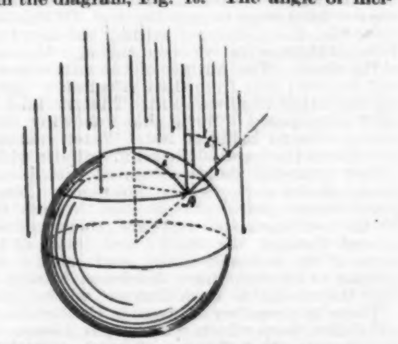


FIG. 10.—Diagram illustrating incidence angle of meteors.

dence is the angle included between the direction of the incident meteor and a line normal to the moon's surface at the same point. It is 0° at the center of the hemisphere turned toward the rain and is 90° at the margin of that hemisphere. At any intermediate point, A, it is measured by the arc connecting that point with the center of the hemispherical surface. Through the point, A, draw a small circle in the plane parallel to the base of the hemisphere. It is evident that the zone of spherical surface above this plane in-

* The Moon: London, 1873, p. 346.

cludes the downfall of all meteors whose incidence angle is less than that of the meteors reaching A, and that the zone below it includes the downfall of meteors making greater angles. The number of those falling on the upper zone is measured by the area of the small circle. The number of those falling on the whole hemisphere is measured by the base of the hemisphere. The ratio of the one to the other, or the proportionate

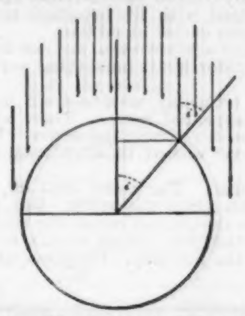


FIG. 11.—Diagram illustrating incidence angle of moonlets.

number of meteors having an incidence angle less than any given angle, i, is equal to $sin^2 i$. Substituting 30° and 60° successively for i, we learn that 25 per cent. of all the meteors have incidence angles less than 30°, and 75 per cent. have incidence angles less than 60°; so that 50 per cent. of the angles fall within the middle third of the quadrant. The law of distribution is graphically shown by curve A of Fig. 12, where abscissas represent angles of incidence, and ordinates the corresponding proportionate numbers of meteors. It will be noted that the number of meteors having incidence angles of 0° or 90° is a vanishing quantity, and that the incidence angle shared by the greatest number of meteors is 45°.

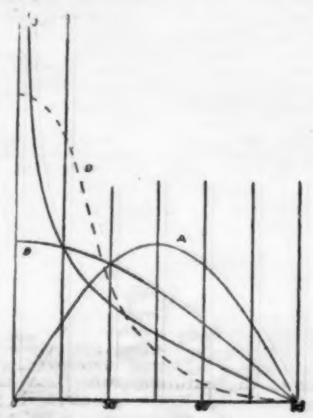


FIG. 12.—Distribution curves. Abscissas = angular deviation from verticality of bodies colliding with the moon. Ordinates = relative numbers of colliding bodies. A = curve for meteors. B = curve for bodies in a single plane. C = curve for moonlets, account being taken of the moon's attraction but not of the earth's. D = type of curve deduced from ellipticities of craters.

In the case of moonlets reaching the moon from the plane of the postulated flat ring, all points of incidence would lie approximately in one plane, which plane would intersect the center of the moon. Postulating, as before, that the distribution of moonlets in this plane is equable, and that they move in parallel courses, and ignoring the attraction of the moon, we have the geometric relations shown in Fig. 11, and obtain $sin\ i$ as an expression of the proportionate number of moonlets whose incidence angle is less than i. This differs from the expression obtained in the case of cosmic meteors, in that it involves the first power of the sine of the angle instead of the second, and there results a very different law of distribution, which is expressed by curve B of Fig. 12. In this distribution law the number of bodies incident at 90° is a vanishing quantity, but the number incident at 0°, instead of being a vanishing quantity, is a maximum, and one-half of all the moonlets have incidence angles less than 30°.

The law of incidence angle for ring-derived moonlets agrees with the law suggested by the roundness of the impact scars, in that it indicates a predominant approximation to verticality, and it therefore accords better with the phenomena than does the law of incidence angle derived from the theory of cosmic meteors. The introduction of the hypothesis of a Saturnian ring thus accomplishes much toward the reconciliation of the impact theory with the circular outline of the lunar craters. Whether it secures complete adjustment is not immediately apparent, and as the question of concordance or discordance is important to the impact theory, the discussion has been carried somewhat further.

The inquiry has followed three lines: first, an investigation of the ellipticity of lunar craters; second, an experimental investigation of the relation between incidence angle and ellipticity of impact craters; third, a more refined investigation of the orbital relations affecting the incidence angles of moonlets.

In the investigation of the ellipticity of the lunar craters I made use of a series of photographic negatives made at the Lick Observatory and deposited by the director of that observatory with the Smithsonian Institution. On these negatives the moon's disk has a diameter of from 5 to 5½ inches, so that measurements of some refinement can be made. It was found practicable to determine the conjugate diameters and through them the ellipticities of 120 craters. In three-fourths of these the ellipticity is less than 0·1; in eleven-twelfths it is less than 0·2; in twenty-nine-thirtieths it is less than 0·3.*

In order to determine the angles of incidence corresponding to these ellipticities it was necessary to ascertain the general law subsisting between angle of impact and resulting ellipticity, and to this end a series of laboratory experiments was instituted. An apparatus was arranged by means of which a ball of plastic clay was made to strike a flat target of the same material at a measured angle and with determined velocity. The angle of incidence was systematically varied, the velocity of impact was varied, and the softness of the clay was varied. A crater similar in appearance to the smaller craters of the moon was readily produced, and it was found that ellipticity is a function not only of angle of incidence, but also of softness of material, and inversely, of velocity of impact. No attempt was made to discover the precise character of this complex relation, because it was immediately evident that experiment could not be made to deal with velocities and strengths of material comparable with those associated with the production of the lunar craters. It was found, however, that ellipticity increases slowly with increase of incidence angle up to 30° or 40°, and with comparative rapidity for higher angles; and the comparison of this relation with observed lunar ellipticities led to the conclusion that from 65 to 90 per cent. of the lunar craters indicate incidence angles of less than 30°. As the theoretic distribution previously derived, on certain assumptions, assigns to but 50 per cent. of the moonlets angles within that limit, it appeared desirable to look more closely into the nature of the orbits of the moonlets as they approach the moon. This examination required mechanical conceptions and mathematic skill I was unable to supply, but I was so fortunate as to enlist the interest of our fellow member, Mr. R. S. Woodward, who made an analytic investigation, on which the following paragraphs are based.

It will be recalled that parallelism of direction was assumed as a means of simplifying the discussion of incidence angle in the case of meteors and moonlets. In the case of meteors the assumption was fairly warranted, but not in the case of moonlets. As the moonlets, by postulate, moved initially in orbits not very dissimilar from that of the moon and in the same direction, their initial velocities with reference to the moon were small as compared with the velocities created by the moon's attraction. Their courses in the near vicinity of the moon were therefore essentially parts of curved orbits of the nature of conic sections, with the moon at the focus, and could not properly be treated as equably distributed straight lines. Furthermore, the initial velocities of moonlets with reference to the moon, that is, the velocities with which they overtook or were overtaken by the moon, were not all the same, but were varied in a systematic way, being greater in proportion as the orbits of the moonlets differed from the moon's orbit.* Account was taken of these relations, but the influence of the earth's attraction, essential to a rigorous discussion, was ignored; the orbital equation of the moonlets was derived, the conditions of collision with the moon were examined, and the general expression for the angle of incidence was obtained.† This general expression is—

$$n = \sqrt{sin\ i}$$

n being the relative number of colliding moonlets whose angle of incidence is less than i. It indicates that 58 per cent. deviate less than 20° from the vertical, 70 per cent. less than 30°, and 80 per cent. less than 40°; and it yields the distribution curve marked C in Fig. 12.‡

The theoretic distribution obtained by this partial treatment accords so well with the phenomena under discussion that greater refinement seems not to be required; but the theory of incidence angle nevertheless offers an inviting field to the mechanist. From the position reached in connection with the present study, it seems probable that the moonlets originally moving in orbits outside the track of the moon would (mostly) reach the inner face of the moon (toward the earth), and the moonlets originally moving inside the moon's orbit would reach its outer face. Approaching the moon in this way, or in any other systematic way, the moonlets would determine and regulate the rotation of the moon. The motion of each moonlet at the instant of collision may be conceived as resolved into two components, one normal to the moon's surface and the other tangential. If the tangential component coincided in direction and velocity with the rotational motion of the moon's surface, the collision would not affect the moon's rotation; but if the tangential component had a velocity greater or less than the rotational motion, the moon's rotation would be accelerated or retarded. The aggregate result of all collisions would be such a rotation of the moon that its surface speed would equal the average of the tangential components of the velocities of moonlet impact. It is evident that if the tangential component of a moonlet's motion coincided exactly with the motion of the moon's surface, the impact phenomena would be the same as though the moonlet fell vertically on a motionless surface; and the harmonious adjustment of moon rotation to the motions of a system of moonlets would reduce to a minimum the ellipticity of craters.

In fine, the hypothesis of the Saturnian ring, by restricting the colliding bodies to a single plane, by substituting a low initial velocity and thus rendering the moon's attraction the dominant influence, and by introducing a system of directions controlling, and therefore adjusted to, the moon's rotation, relieves the meteoric theory of its most formidable difficulty. It also explains in a simple way the abundance of colliding bodies of a different order of magnitude from ordinary meteorites and aerolites. The remainder of my discourse will be devoted chiefly to the development of the moonlet theory, and I hope to show that it not only harmonizes with the varied details of crater character, but aids in the explanation and even in the discovery of other features of the moon's face.

The idea that a planet or satellite may be developed from a ring of matter revolving about the primary has been entertained by so many students of celestial mechanics that its introduction needs no defense. The assumption that the ring about the earth was thin and disk-like rests legitimately on the analogy of Saturn's ring. The idea that the ring, although possessed of sufficient stability to assume a definite form, nevertheless suffered some disturbance or underwent some process of evolution by which its stability was destroyed, is likewise familiar to celestial mechanics, and it does not appear necessary in this conection to speculate as to the precise manner in which the integration of its discrete elements was effected, nor does it appear necessary to assume, on the one hand, that the aggregates of ring matter constituting the larger moonlets were loosely assembled, or, on the other hand, that they were already welded into continuous masses; provided the energy of impact with the moon sufficed to produce phenomena of fusion, the dynamic results would perhaps not differ greatly.

The velocity of impact, depending chiefly on the moon's attraction, must be supposed to have increased gradually as the moon grew. In the closing stages of the process it did not vary greatly on either side of one and one-half miles per second, and the phenomena of the present surface may be discussed on the basis of that velocity. The energy due to that velocity would more than suffice, as already stated, to melt the moon let if it were composed of ordinary volcanic rock and provided all of the energy were applied to the heating of the moonlet. Practically only a portion of it was thus applied; another portion produced heat in the contiguous tract of the moon's material; yet another was consumed in the deformation of moonlet and moon resulting in the crater, and another resulted in modifications of the moon's motions, changing its orbit, its orbital velocity, its axis, and its rotational velocity. The energy converted into heat might be regarded as the remainder after deducting all other effects, and the resulting temperatures would be further conditioned by the distribution of heat in the colliding masses.

Since the area of the moon's surface directly struck by the moonlet is a function of the square of the diameter of the moonlet, while the energy applied to that area, being measured by the mass of the moonlet, is a function of the cube of its diameter, more energy would be applied to a unit of space in the case of large moonlets than in the case of small, and the temperatures caused by large moonlets would therefore be greater. To this relation I ascribe the restriction of inner plans, indicative of fusion, to the larger craters, and the same explanation applies less directly to the limited distribution of central hills.

In the production of small craters by small moonlets I conceive that the bodies in collision either were crushed or were subjected to plastic flow, and in either case were moulded into cups in a manner readily illustrated by laboratory experiments with plastic materials. The material displaced in the formation of the cup was built into a rim, partly by overflow at the edges of the cup, but chiefly by outward mass movement in all directions, resulting in the uplifting of the surrounding plain into a gentle conical slope. This outward and upward movement was accentuated, possibly through the agency of heat, about the immediate edge of the cup, occasioning the special elevation called the wreath. The cups thus formed, having dimensions commensurate with the strength of the lunar material, were stable and permanent. The impact of a larger moonlet produced a larger cup, and at the same time fused a portion of the material and softened other portions. The walls of this cup were so lofty that they could not sustain their own weight, and they

* Measurement was limited to the larger craters because the photographs did not indicate the outlines of the smaller with sufficient precision. Craters near the limb were ignored because inequalities in the heights of their rims might vitiate the results, and also because the perspective foreshortening makes it practically impossible to determine the directions of the longest and shortest diameters. Probably some of the measures made are affected by the latter difficulty and the ellipticities consequently underestimated, but the uncertainty thus introduced is thought to be less than would be added by throwing out all the craters obliquely seen and thus reducing the number of instances on which generalization is based. The number of measurements could be largely extended by direct telescopic observation.

* Assuming circular orbits for moon and moonlet, calling their distances from the earth D and d, and calling their velocities in their orbits V and $V + u$, we have, from Kepler's third law,

$$\left\{ \frac{(V+u)\ D\pi}{V d \pi} \right\}^2 = \left(\frac{D}{d}\right)^3, \text{ whence } \frac{D-d}{d} = u\frac{2\ V+u}{V^2}$$

Since, in the case of any colliding moonlet, u is very small in comparison with $2\ V$, the fraction in the second member is sensibly constant, and u, the relative velocity of moonlet and moon, varies as $\frac{D-d}{d}$ or approximately as $D - d$, the distance between the orbits.

† At a distance, c, from the moon's center a moonlet has the initial velocity, u. Placing the origin at the moon's center and the axis of reference parallel to the direction of the initial velocity, the polar equation to the moonlet's orbit is—

$$\rho = \frac{b^2 u^2 / \mu}{1 + \frac{a}{c} \cos\theta - \left(\frac{b}{c} - \frac{bu^2}{\mu}\right) \sin\theta}$$

where ρ is the radius vector, θ its inclination to the axis of reference, b the length of a perpendicular drawn to the axis from the point where the velocity is u, a the distance from the foot of that perpendicular to the origin, and μ the constant of gravitation for the moon.

The radius of the moon being r, the condition that the moonlet collides with the moon is—

$$u^2 < \frac{2\mu \left(r - \frac{r^2}{c}\right)}{b^2 - r^2}$$

The general expression for the angle of incidence, i, is—

$$sin\ i = \frac{b}{r\sqrt{1 + \frac{2\mu}{ru^2}\left(1 - \frac{r}{c}\right)}}$$

in which $2\mu / r = V^2$ = the square of the velocity acquired by a body falling to the moon from an infinite distance. Since r / c is a small fraction and $2\ \mu / ru^2$ is a large number—

$$sin\ i = \frac{bu}{rV} \text{ (nearly).}$$

By postulate (preceding note) u varies as b, and since r and V are both constant—

$$b = \sqrt{sin\ i} \times \text{constant.}$$

‡ The curves A, B, and C of Fig. 12 represent the distribution of incident bodies with reference to angles of incidence under the laws expressed severally in the formulas:

$$n = sin^2\ i, \quad n = sin\ i, \quad \text{and} \quad n = \sqrt{sin\ i}$$

n being the percentage of bodies whose incidence angle is less than i. The graphic representation of n in each case is the area beneath the curve from the vertical axis to the ordinate corresponding to i. The curves themselves represent the differential equations:

$$\frac{dn}{di} = 2\ sin\ i\ cos\ i, \quad \frac{dn}{di} = cos\ i, \quad \frac{dn}{di} = \frac{cos\ i}{2\sqrt{sin\ i}}$$

in which $d\ n$ is the relative number of bodies having the incidence angle, i.

were further weakened by the effects of heating; consequently they settled downward and their lower portions flowed inward toward the center of the cup. The inward flow from all sides produced at the center an upward movement, occasioning the central hill. The effect was perhaps heightened by the elastic recoil of a considerable tract of the moon's mass below and about the point of impact. At the same time the fused parts which were partly determined by the distribution of strains and partly by the occurrence of local passages of more fusible material, flowed to the bottom of the cup, either surrounding the central hill or, if in great volume, submerging it. Sometimes minor tracts of fused matter occurred in the wreath, and the exudation of these gave rise to lava streams flowing down the outer slope. The inward flow of the lower portions of the walls undermined the upper portions, including the inner part of the wreath, so that they settled down toward and into the liquid pool of the interior, and this settling gave rise to the inner cliff and the inner terraces. In the case of some of the large craters all of the wreath was carried down.

The effect of the collision on the moonlet was not uniform throughout. The part in immediate contact with the moon, being compressed by the shock of the entire mass behind it, was probably heated more than any other part. The opposite portion of the moonlet, sustaining no blow from behind and having its motion arrested in a comparatively gradual way, was less affected and probably never fused; the results of laboratory experiment indicate that it remained central in the crater and was uplifted by the recoil so as to constitute the surface of the central hill.

The impact theory as thus developed appears competent to explain the origin of all typical features of the lunar craters. Its relation to exceptional features, as well as to associated phenomena, will presently be considered; but something should first be said with reference to certain physical factors of the process which are somewhat unfamiliar.

The production of heat by impact is a well known phenomenon, but instances in which that heat suffices to produce fusion are somewhat rare. During the earlier discussion of the doctrine of the conservation of energy Hagenbach fired a leaden bullet against an iron target,* melting a portion of the bullet. By a computation involving the velocity of impact, the weights of the melted and unmelted portions of the bullet, and the physical constants of the materials, he was able to account for more than 90 per cent. of the energy, and the theoretic relations between molar motion and heat were thus substantially verified. In ordinary rifle practice in a shooting gallery the small leaden bullets fired against the iron targets are both fused and rendered incandescent by the shock. In the course of my own experiments a small amount of fusion was produced by firing a ball of Wood's alloy against a target of the same material.

Central hills have not been produced in the laboratory by the impact of rigid materials, it being found impracticable to conduct operations on a sufficient scale, but they are readily formed with semi-liquid substances. If a drop of water be made to fall on a still surface of water, the outward moving annular wave at one instant incloses a crater; at the next instant a mound rises in the center of the crater. If for the water there be substituted a thin mud, the relations may readily be adjusted so that the viscosity of the material will arrest the motion in either phase. If the drop fall from a certain height, it produces a cup-like cavity with a smooth rim; if it fall from a somewhat greater height, it produces a larger cup with smooth rim and with a smooth, dome-like hill in the center (Fig. 13). Though this experiment does not

FIG. 13.—Central hill formed experimentally by gravitational recoil.

yield forms closely resembling those of the moon, it serves to illustrate the process of gravitational recoil in the formation of a central hill. The peculiar conditions ascribed to the lunar phenomena, and especially the fact of local softening and fusion, seem adequate to account for the observed differences in form, but it has not been found possible to reproduce them on a small scale.

Arched Floors.—In general, the inner plains of the craters are level, except as interrupted by central hills and by craters of subsequent origin. In some of the larger it is possible to note, under favorable conditions of light and shadow, a gentle convexity corresponding to the normal curvature of the moon's surface. In a few instances, not more than a dozen in all, the convexity is seen to be greater, the central portion distinctly rising above the level of the margins. This peculiarity is most strongly marked in the floor of the crater Mersenius, which is a dome 1,500 feet high and thirty miles across. A similar but lower dome in the crater of Petavius bears on its crest a group of peaks exhibiting the ordinary characters of the central hills. Two explanations have occurred to me, each based upon the idea of a relatively soft substratum. It appears possible that deep-seated matter which had been displaced horizontally by the original collision might slowly return under gravitational stress, lifting the middle of the crater floor after congelation of the impact liquid had given it a level character. It also appears possible that the strains produced by the tendency of viscous material to flow upward were not effective until re-enforced by the shock associated with the formation of some later but neighboring crater. In either case the result was produced by the flow of a viscous solid analogous to the viscous movement supposed to accompany the broader terrestrial uplifts. The fact that the arch of Mersenius is cracked at the crest and that the arch of Petavius is traversed by a system of cracks is consistent, I think, with either of these explanations, but is perhaps not specially significant, as cracks occur in considerable abundance in many parts of the moon's surface.

Distribution and Overlap.—Consideration will presently be given to the fact that in certain districts craters are thickly set and elsewhere they are less numerous, but in other respects their distribution exhibits no system. They are not arranged in lines or other patterns, large and small are indiscriminately mingled, and interference is a common phenomenon. If, as I have assumed, the moonlets approached the moon approximately in the plane of its equator, the fact is not attested by the grouping of the craters in a medial zone, and so it is necessary to assume further that the axis of rotation was not constant. This assumption need occasion no difficulty, for unless the approaching moonlets moved *precisely* in the plane of the moon's equator, their collisions would disturb its axis of rotation, and there is no reason to suppose that these disturbances would be compensatory rather than cumulative. Under the successive impulses thus given the moon's equator may have occupied successively all parts of its surface, without ever departing widely from the plane of the moon's orbit.

(*To be continued.*)

* Pogg. Ann., vol. 140, 1870, p. 486.

THE CODY-MEYER MATCH.

HORSEMAN against bicyclist! This, in the opinion of amateurs, has not much significance from a sporting standpoint. It is just as if a boat and a balloon or a locomotive and a carrier pigeon were matched against each other. The terms of comparison totally fail.

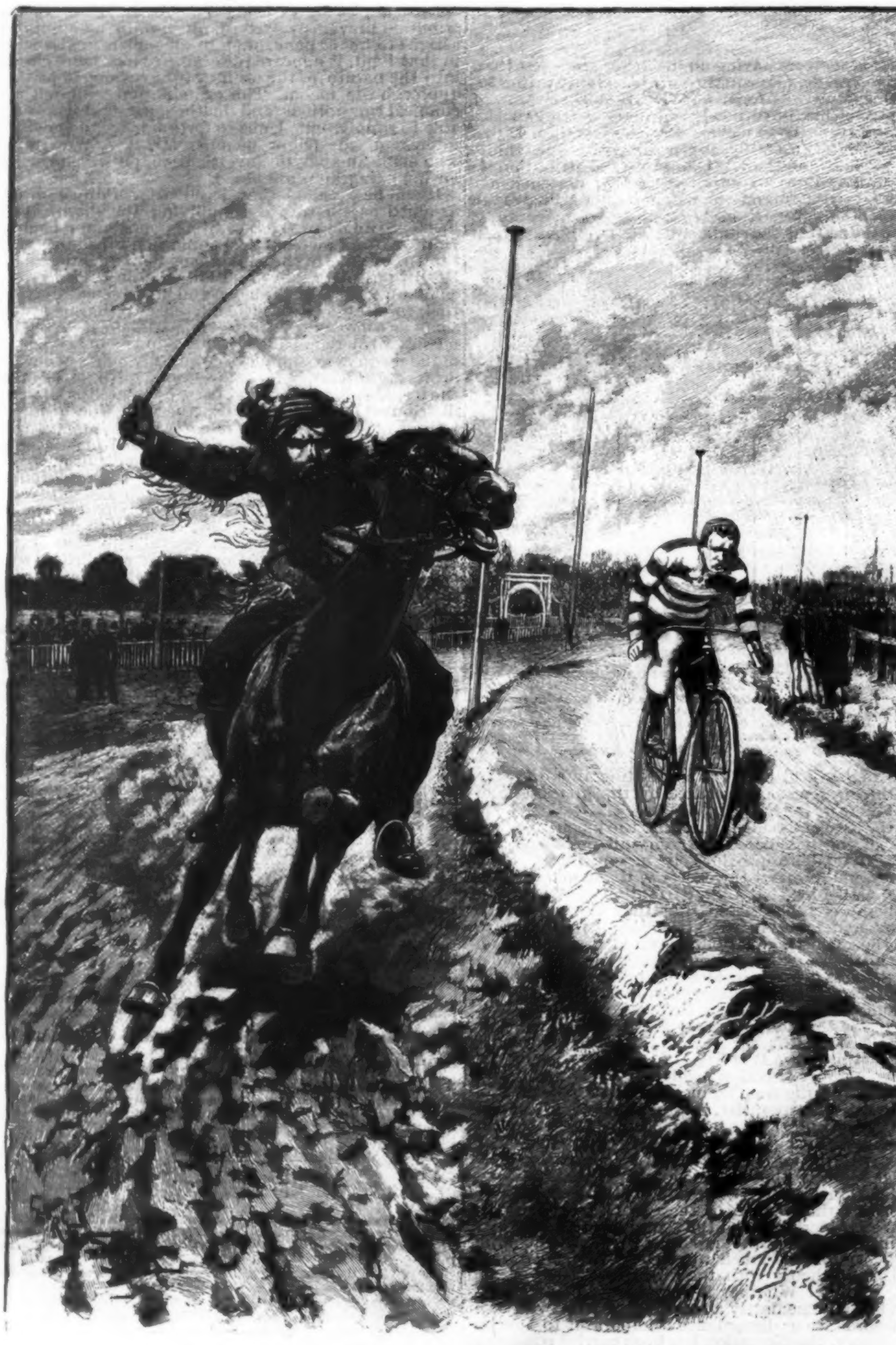
As a spectacle, it is another thing. The Athenians of Paris, surfeited with all sorts of pleasures, eagerly seized the occasion that was offered them to see something new, represented by a race between Cody, the king of sharpshooters, the king of the cow boys, and the king of anything you wish, and Meyer, a wheelman of a certain endurance. The conditions stipulated that the race (with one of those stakes such as Marseilles knows how to announce upon its flaming posters) should be run at Levallois three days in succession, at the rate of four consecutive hours per tourney, and that the one that made the greatest number of kilometers should be victor. The cyclist had the right to change his machine, but he could not have himself towed. The horseman had at his disposal ten horses, which he mounted at his will, only the completely jaded animal having to be replaced; slight accidents, such as going lame and getting out of wind, did not count, or at least counted in favor of the bicyclist.

At the appointed hour Cody and Meyer made their appearance at the starting point. The curiosity of the spectators was immediately directed to the horseman, who was clad in a theatrical costume of the plains, with immense boots, a buckskin jacket edged with hair, and a many-colored handkerchief upon his head. A fine lad, indeed, with his luxuriant mustache and his wealth of long curled blond hair.

He was too fine a fellow even, and too large and too strong for the unfortunate horses that were destined to carry him.

These latter, let us say, were not all outside show. Two or three appeared better. There was, even, one quite handsome cob, strong and active. But to crown all, the cob never wished to allow itself to be straddled.

The race began. The racers shot off, each on his own track, with wonderful spirit. Did Meyer spare himself or was the ground bad at the start? The latter was rather the case. At all events, he lost twelve kilometers on the first day. Cody was extraordinary.



RACE BETWEEN HORSE AND BICYCLIST.

He rode like an Indian. He attacked his horses with an energy that cost him four whips in one afternoon. He urged them on at the top of their speed without any consideration. It was said that on the following days the poor jaded beasts would allow themselves to be distanced by the machine. After every three rounds Cody abruptly stopped his horse, left it standing upon the track and jumped upon another that grooms held all ready. This change of horse required but a few seconds.

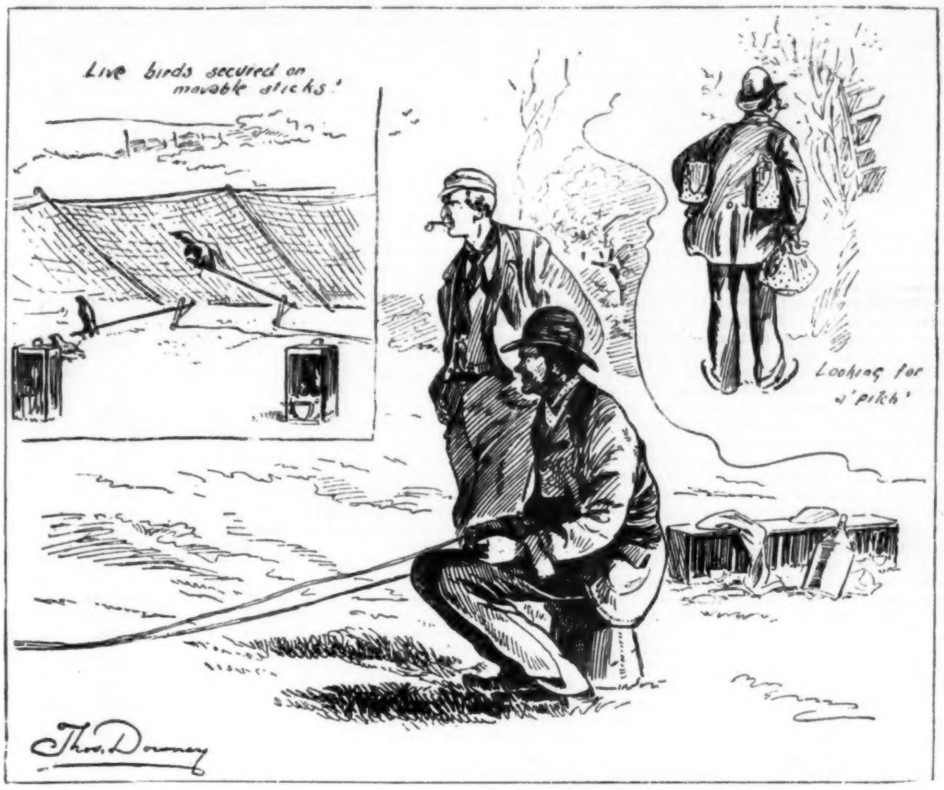
Cody, contrary to expectations, won, having caused his ten horses (reduced to seven on the second day) to make 349 kilometers in 12 hours, against 332 covered by Meyer.—*L'Illustration.*

THE length of the Tay bridge which fell, 1879, was 10,612 feet, ninety feet above the water level, eighty-five spans. The new Tay bridge was begun in 1882.

THE LONDON BIRD-CATCHER.

THE suburban bird-catcher goes out to Tooting, to Lea Bridge, and to Parliament Hill, and with his "call birds," his birdlime, and his "back-folding" nets—an equipment which is not very expensive, but varies in value according to the efficiency and number of his "call birds"—contrives to make a very decent living out of his profession. Bird-catching is quite a business. Some of the large bird-fanciers' shops which are scattered about the "Dials" and Drury Lane have a number of bird-catchers in their employ, five or six or a dozen; but more generally the bird-catcher sets up for himself, and sells his catch in the best market. Any one, as the fanciers will tell the inquirer, can become a bird-catcher. No license is required, nor any very great skill; merely a good deal of patience; two or three back-folding nets, and, perhaps, one or two "call birds." Sometimes the catcher does not even have trained decoy birds, but only uses birds tied on movable sticks, or linnets penned in cages. A good "call bird" is valuable, and is trained to come to its owner's whistle.

There are two or three kinds of nets, of which the back-folding variety is the most useful. The simplest net is that which is propped upright by sticks and is pulled down upon the birds. The "back-folder" is a double net, and lies flat upon the ground, in such a way as to leave about six inches space between the two halves of it. When the birds alight on this six inch space between the nets, the two halves close over like the leaves of a book, and the birds are captured. It is not only from the suburbs of London that the birds come; Hastings, Brighton, and St. Leonards contribute large numbers, especially at this time of year. Goldfinches come from Wales, and a good many from Evesham, Gloucester, and Hereford. Round about London the chief business is done in linnets. Prices fluctuate at this time of year; birds, owing to the plentiful supply, are very cheap. In spring, when the birds are scarce, linnets fetch as much as 6s. or 8s. a dozen for cock birds. Hens can be bought at 1s. a dozen. Goldfinches are dearer, though a cheap variety is now coming in from France. During the last few weeks as many as 20,000 gold finches a week have been imported from France. The market price is a franc a pair. These prices are, of course, in marked contrast to those which are paid for trained birds. The trained birds, however, are seldom caught. They are generally "branchers," that is, birds reared in captivity, and are taught the "julks" by older birds. A good linnet, which can be relied upon to sing two or three score "julks" in a quarter of an hour's race is worth from £5 to £6. A "corussal-chay" goldfinch, that is, a goldfinch whose song is "si whippet si whippet corussal-chay!" will fetch as much as £9 or £10.—*Daily Graphic, London.*



LONDON BIRD-CATCHERS AT WORK.

THE CHURRUK POOJAH OR SWINGING FESTIVAL IN A BENGAL VILLAGE.

"A QUESTION was asked recently in the House of Commons of the Under Secretary of State for India whether his attention had been drawn to the existence of a hook-swinging festival at a village only seventeen miles from Calcutta, at which it was stated that the hooks had been passed into about two and a half inches of the skin and flesh of the man's back; and whether the government of India would be urged to put an end to the annual recurrence of these festivals. —Sir E. Grey replied that it had previously been brought to the notice of the Secretary of State by the government of India in June, in reply to a dispatch asking them, with reference to recent cases in Madras, to consider how the practice of hook-swinging might best be finally extinguished. He had not yet received the proposals of the government of India. The ceremony as shown in our illustration is thus described by the artist: 'After a short interval of waiting, a devotee, one of several through whose back muscles the hooks had been passed in readiness, was tied to the end of the cross pole, lowered by tilting for the purpose; and being securely fastened was lifted up into the air with hands folded on the chest and the body fairly hanging by the hooks passed through the muscles of the back without any other auxiliary support. . . . . The pole was then rotated by pulling on the ropes at the counterbalance end, its attachment to the vertical post permitting of free rotation.'"—*The Graphic, London.*

ALMOND OIL.

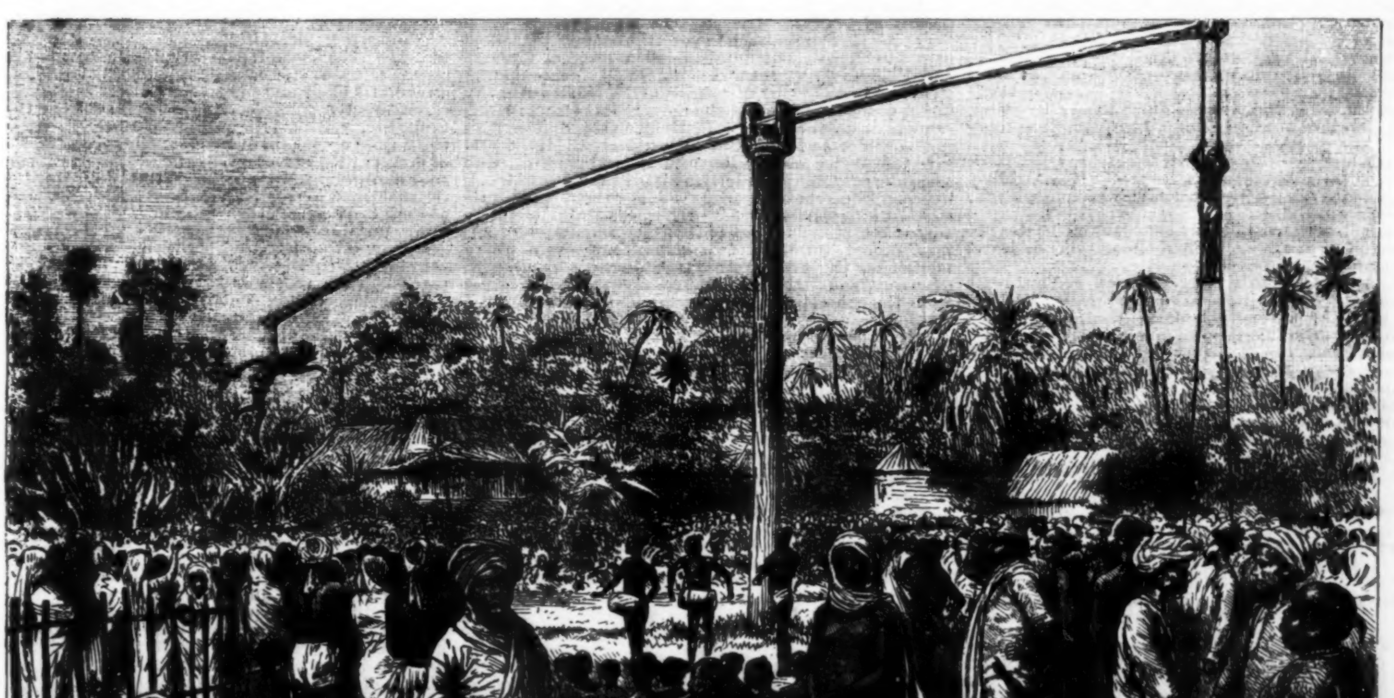
ALMOND oil is obtained from the fruit of the almond tree (Amygdalus communis), indigenous to Persia, Syria, Asia Minor, and Algeria, and now found growing generally in Southern Europe. There are two varieties of fruit—the sweet almond and the bitter almond. The latter is the principal source of "almond oil," the former being commonly eaten as a nut. Two kinds of oil are obtained from almond nuts:

1. A fatty or fixed oil.
2. An essential oil.

The latter is obtained from the almonds before the former has been expressed. The essential oil contains minute quantities of prussic acid. We are at present, however, mainly concerned in this article with the preparation and properties of the fixed oil of almonds.

PREPARATION.

The fixed oil is obtained by pressure. In the case of sweet almonds the nuts are pressed unpeeled, but when bitter almonds (as is mostly the case) are employed,



THE CHURRUK POOJAH OR SWINGING FESTIVAL IN A BENGAL VILLAGE.

the nuts are peeled and deprived of their essential oil, and then crushed in bags, by which means the fixed oil is forced out and a residual cake left behind. In many cases expression is carried on at a comparatively high temperature, resulting in a bigger yield of oil. The yield varies from one and a quarter pounds to two pounds from five pounds of almonds. The best quality oil is said to be obtained from the almond trees of the island of Majorca, though the industry is extensively carried on in Spain, Italy, and Southern France.

GENERAL PROPERTIES.

Almond oil is transparent and of a pale yellow color. It is very mobile for an oil, running very freely over surfaces. It is odorless, but possesses an agreeable flavor. Its sp. gr. ranges between 914—920 at 15° C. On being cooled to 20° to 25° C. it solidifies. It is readily soluble in ether or alcohol requiring of the latter body 25 parts in the cold and 6 parts hot to effect complete solution. It soon turns rancid on exposure to the air.

COMPOSITION.

Almond oil consists chiefly of triolein and tripalmitin, together with the homologues of the latter. Some authorities say that cholesterine, a peculiar body found in bile, is present in almond oil. Triolein is present in the larger proportion, amounting to nearly 75 per cent. of the oil.

REACTIONS.

Bromine Absorption.—Bitter, 26·3.

Temperature rise on addition of sulphuric acid, 50° C.

Saponification Equivalent.—285-296, requiring from 19·47 to 19·61 per cent. of caustic potash (KHO) to complete saponification.

Elaidin Reaction.—Dissolve 1 c. c. of mercury in 12 c.c. of cold nitric acid, sp. gr. 1—42. Add 2 c. c. of the solution to 50 c. c. of oil in a wide necked stoppered bottle, and shake vigorously every ten minutes for two hours, keeping the temperature fairly regular. Almond oil gives a solid hard mass.

Color Reactions.—(*a*) Sulphuric acid (strong). To twenty drops of the oil in a porcelain dish add four or five drops of the acid. Observe color:

1. Before stirring—colorless or yellow.
2. After stirring with a glass rod—dark yellow.

(*b*) Nitric Acid.—1. Add 1 cb. c. of nitric acid, sp. gr. 1·32 to 4 cb. c. of oil, and agitate. Heat tube in hot water for five minutes and then allow to cool. The oil remains colorless, and finally assumes the form of a white solid.

2. Take 5 cb. c. of oil and cautiously add an equal volume of red fuming nitric acid. A bright, narrow green belt will be observed at junction of acid with oil. The remainder of oil is usually opaque or flocculent.

(*c*) Mercuric Nitrate and Sulphuric Acid.—To twenty drops of oil in a porcelain dish add ten drops of mercuric nitrate and then five drops of strong sulphuric. A light brown reddish coloration is produced.

(*d*) Fuming Nitric Acid and Water.—Take 7·5 cb. c. of oil and add 1·5 cb. c. of fuming nitric acid and 1 cb. c. of water. Well agitate. The mixture turns white, and after a few hours forms a solid white mass, the liquid remaining nearly colorless.

(*e*) Zinc Chloride.—To 10 drops of the oil in a porcelain dish add five drops of zinc chloride. The color may turn to white or the oil is not affected.

ADULTERATION.

Almond oil is frequently adulterated with the poppy oil, rape oil, sesame oil, peach oil, and apricot oil. Taking the above tests and reactions, the following may be noted:

1. Bromine Absorption.—A high bromine absorption indicates possible presence of sesame, peach, or apricot oil.
2. Elaidin Reaction.—If solidification is retarded, suspect presence of rape oil or a drying oil like poppy oil.
3. Color Reaction (*a*).—If a reddish or brownish tinge appears, suspect presence of peach, apricot, olive, poppy, or rape oil. A greenish color also indicates the presence of rape oil.
4. Color Reaction (*b* 1).—Any coloration indicates the presence of a foreign oil. Red coloration indicates more particularly rape oil.
5. Color Reaction (*b* 2).—Any general red or brown coloration indicates adulteration. Brownish tints indicate peach or apricot. A dark green zone with a pinkish coloration in oil shows presence of poppy oil.
6. Color Reaction (*d*).—If the mixture turns red or brown, suspect presence of cottonseed, sesame, or earthnut oil. If the solidification is retarded or not complete, suspect the presence of a drying oil
7. Color Reaction (*e*).—A purple brown color indicates presence of peach oil, and a dark brown apricot oil. The specific gravity should be taken before the chemical tests are proceeded with. A high sp. gr. indicates the presence of such an oil as poppy, sesame, cottonseed, or peach.—*Oils, Colors and Drysalteries.*

THE EQUIPMENT OF ENGINEERING SCHOOLS.*

By ROBERT H. THURSTON, Director of Sibley College, Cornell University.

The Equipment of an Engineering School has come to be, in these later years, a vastly more important and extensive and costly accessory to the school than was dreamed of a generation ago. The fact has come to be recognized that the school or college of engineering, like those of law and of medicine, is properly and necessarily, if it is to be efficient, the place and the means of training young men for a learned and exacting profession, not, as once seemed the impression generally, that it should be regarded as a boy's high school, in which a feeble general education should be supplemented by still more rudimentary lessons in science, the milder sort of "higher mathematics," and a suggestion of the simplest elements of surveying, if the course be distinctively civil engineering, or of draughting and kindergarten shopwork, if one of mechanical engineering. The profession of engineering has not only been established as a learned profession in the generation just passed, but it has come to exact of its novices, where trained in the most advanced and successful schools, a more extended preparation, a more arduous professional course, than are demanded to-day by the schools of either law or medicine; and this fact, if there were no other corroborative of the conclusion, has fully established the engineer in his position as a member of a profession and of a learned profession.

The necessity of conducting the student, already proficient in the elements of the mathematical and physical sciences, through a course of instruction that shall give him familiarity with the principles underlying every operation which, as a practitioner, he must later conduct or direct, compels the schools to provide themselves with all the apparatus of instruction in the physical and chemical laboratories. This was admitted and practiced years ago in the better class of engineering schools; but of late it has come to be also seen that a truly professional school in this department, and in the highest grades, must also be prepared to give instruction in the methods and practice, in the actual conduct, of all those operations which involve the application of scientific processes and exact measurement; in all the standard methods of determination of the value and of the distinguishing characteristics of the materials employed in construction, and in the ascertainment of the efficiency of such motors and machines as the engineer employs in professional work. This brings in the necessity of an outfit, including, in the case of the civil engineering schools, not only the instruments of surveying and observation, but testing machines and apparatus of the laboratory for testing materials of construction; in the case of the school of mechanical engineering, a whole series of extensive and complete workshops, the mechanical laboratory for testing materials and the experimental machinery, such as steam, air and gas engines, steam boilers and other costly apparatus, peculiarly necessary in the instruction of an engineer whose province it is to design, to construct, to operate and to determine the value of all kinds of machinery. So extensive and so costly have become these equipments of the great engineering schools in the United States, that it has come to be seen that only a large capital can secure such an outfit as can now be made useful in undergraduate and in post-graduate work, and that, however large the available funds, only wisdom, experience and the utmost care in selection can make the equipment of the best and most wealthy of these schools yield maximum returns. It is thus important to consider what principles should govern the officer in charge of this kind of instruction in the planning of a proposed equipment, the selection of its elements, and the emplyment of the whole in such a manner as shall give the largest amount of instruction at the lowest cost of annual operation. It is this problem that it is proposed here briefly to study, with the purpose, mainly, of inducing discussion and a comparison of views and of experiences among those members of the Engineering Congress who are most interested in securing the best solution.

The Nature of an Equipment, such as should be given an engineering school of the highest professional standing, is by no means unanimously determined by either practitioners or professors. In Europe, comparatively few schools of this class have what would be considered, in this country, an equipment for professional instruction. A moderately good outfit in physics and in chemistry, for example, is all that is possessed by one of the most famous of all the schools of France. Few German schools have what we term a "mechanical laboratory," for testing materials, open to students or used in regular instruction of students in engineering. No British school has yet approached our ideal of a satisfactory outfit; although a number have secured single large testing machines and "experimental steam engines." One distinguished English authority and a professor in one of the most reputable of British schools of engineering explicitly declares that he does not consider such equipments desirable. He would give the novice instruction in the mathematical and scientific principles underlying the practice of engineering construction, and would then send the student into the field or into the works of the manufacturing establishment to obtain the remainder of his professional training. He would not even use a model, on the ground that the engineer deals with drawings, and that the graphical representation, rather than the concrete substance, should be made familiar to him.

But I think it has come to be well recognized in this country, at least, and is coming to be seen abroad, as a result largely of our successful practice, that the more the young engineer is systematically and thoroughly trained in the professional as well as in the scholastic work distinctive of his field, the better engineer does he become. It is also coming to be seen that—and especially in the case of the young mechanical engineer—a month of this regular, scientific, systematic training in professional work is worth more to him, is more productive of result, than years spent in the haphazard, irregular, and always more or less incomplete, training of commercial establishments. In fact, the exact methods of science, as taught in the best schools, can never be learned in the field or in the shops; which often train the young engineer to habits of inaccuracy, and make him inclined to be shiftless, and content with low standards of excellence, such as are likely to ruin his future rather than give him aid in his efforts toward advancement and professional success. It may be taken as settled that the best judgment of the best authorities has been declared in favor of a material equipment for the engineering school, and a very complete and extensive one. What shall it be? That is the present and the live question for us.

Speaking generally and broadly, it seems sufficiently obvious that the equipment of every engineering school should be such as will best illustrate the scientific principles taught in its elementary work and the processes of engineering practice which naturally constitute essential parts of the work of instruction in such schools, and can be better taught there than in the uncertain and unsystematic school of regular engineering practice—such as will afford opportunity for the acquirement of familiarity by actual touch and practice with all those methods of scientific research in engineering which are now so commonly and so generally found to be essential elements of professional preparation for the practitioner, and which cannot usually be learned with any degree of accuracy, completeness, and satisfaction, if, indeed, they can be taught at all, outside the engineering school. Above all, it may be said, in speaking of the higher schools of engineering—the professional schools without admixture of the diluting elements of extra-professional work—the equipment should comprehend all that is needed to make them capable of supporting, as graduate departments, systems of instruction in all the most advanced lines of applied science in engineering and of carrying on and promoting scientific research in fields still unfamiliar to the practitioner, but in relation to which he is daily compelled by the rapid advance in professional and general practice to seek additional information, or within which unexplored fields are constantly arising problems challenging solution. Scientific investigation and research in all departments of engineering are coming to constitute the main lines of advance and the principal occupation of scientifically trained graduates of the schools pursuing advanced work. That equipment is thus best which, within the range of work of the school for which it is intended, gives the most complete facilities for illustrating its courses of instruction, and, if it reaches so high, for research through the best methods of applied science, and at least cost for purchase and for most effective use in its legitimate employment.

Exact Adaptation to its Purpose may be thus assumed as the primary requisite in the establishment of an outfit for any engineering school. The courses of instruction should be first and thoughtfully planned with a view to high efficiency of instruction and most perfect fitness to the object in view. Their illustration by a collection of equally well-chosen apparatus is the next step of preparation for work. The last of all methods of equipping any school is one which is, nevertheless, sometimes observed—the collection of all sorts of apparatus and machinery, whatever or however they may be obtained, and the subsequent distortion of the courses of instruction to bring them into play. One simple, inexpensive, piece of apparatus, or one bit of machinery, illustrating well an essential principle, is worth more than the most imposing and costly piece of apparatus or collections of costly machines, of which the main value is that of the museum.

One thousand dollars expended in the purchase of the simple and complete series of illustrations of mechanical principles, taught in the earlier part of the course of instruction in the engineering school, has more intrinsic and paying value than ten thousand dollars paid for some costly but seldom needed instrument or machine, the elementary collection lacking.

The Elementary Outfit should be the first secured, and if any difference were allowable, the most carefully chosen. It is here that a stated sum may be made to do most good. It will purchase the largest number of useful illustrative apparatus, will render efficient the instruction of the largest number of students, and will do most, in all ways, to make the work of the school efficient. The equipment for illustration of the course of the first year should be purchased first and with most liberality of expenditure; next, the outfit for the second year should be procured; then, that of the third year and of the latter part of the course; and, finally, a sufficient amount of capital being available, there should be gathered together, first the simpler and then the more ambitious portions of the equipment of the department of experimental engineering and of research. Every principle and every method should be illustrated where practicable, and by concrete apparatus and mechanism—by the real, *live* machinery and apparatus of actual practice, whenever possible, if it be the methods of engineering that are to be exemplified. The outfit of the elementary portion of the course is commonly easily obtained, and its place and purpose are so definitely fixed by the character of the course to be illustrated that no hesitation will be felt ordinarily either in regard to the nature or the quantity of the illustrations. Choice of quality is often allowed, and, as a general rule, exact adaptation to its purpose is the one requisite to be insisted upon in selection. On the one hand, no defect of design or construction should be allowed; on the other, nothing should be wasted on unnecessary polish or inappropriate and costly material. As moderate cost as is consistent with good form, material, workmanship and finish, and with durability, should be insured. Good judgment and deliberation in choosing precisely the right method and apparatus of illustration will usually provide all that can be advantageously employed in the elementary departments with a moderate expenditure of capital.

The Tools of Trade constitute in all engineering schools an essential part of the equipment. They are needed not only in illustration of the principles and methods of work, but also and mainly for use in the practice of the art, with a view to giving every student familiarity by its practice with all its essential operations. These instruments and tools should always represent the most serviceable makes, and should be excellent in design and construction, with no superfluous finish or ornamentation, and, above all, thoroughly accurate. They should represent the apparatus and tools of the best practitioner as chosen by him for utility and durability. Accuracy and reliability are the first requisites; convenience, handiness, portability where transportable, should also be insisted upon. Where perfectly practicable, when numbers are required of the same kind, the makes of several, always of the best, manufacturers should be included in the outfit, in order that the student may be able to observe the differences among them, their several advantages and disadvantages and their excellencies and defects, as well as make himself familiar with their peculiarities, with a view to becoming competent to use them all, whenever and wherever met with in later practice.

Such collections of tools, to be of maximum value, must be selected, each with a definite purpose, accessory to the main purpose of the school, to which it should be adapted most perfectly. To this end, the plan of operation of the establishment must first be exactly determined, and fully planned in every detail, and the kind and quantity of every sort of tool needed should be predetermined. If the school is to be, mainly, a manual training school, the exercises will presumably be graded from those requiring comparatively little

* Introduction to a discussion before Division "E" of the Engineering Congress at Chicago, August, 1893.

skill in the use of the simplest tools to those exacting the highest skill and the use, with ease, accuracy, and certainty, of the most important machines, and the concluding courses should be regular exercises giving the desired manual training, with more or less of instruction in the processes of construction and assemblage of parts and complete products.

If the school be one of mechanical engineering of the highest grade, for example, and its students men of some maturity and ambition, pursuing a course of purely professional training, the shops of the school must be prepared to illustrate all the processes of the trades subsidiary to that branch of engineering, to aid instruction in every elementary principle and in all applications of wood-working, blacksmithing and toolmaking, foundry work and machinist's work, that commonly contribute to the development and completion of the engineer's designs. The course to be given will have been properly planned in all details, in advance, and the outfit selected in such manner that every tool needed will be supplied, each in the number required to do the total work demanded of the kind for which it is specially contrived, and with the result, when the shops are in operation, of keeping every tool constantly working, and of invariably meeting every demand for the specific operation contemplated by the designer of the course and of its products.

In such shops it is usually considered desirable that the course should begin with so much of manual training, in each of the trades, as will give the novice a fair degree of familiarity with the tools, their purpose and their use, as well as with the character of workmanship attainable or desirable—the finest workmanship is not always the best in business—following this preliminary instruction by the more ambitious work of actual construction of one or more standard articles of manufacture. These articles are so chosen as to illustrate best the largest number of mechanical operations, while, if possible, producing a machine or other product of interest and value in itself, both as seen from the point of view of the instructor and from that of the engineer. The collection of an outfit of tools for such purposes as these evidently involves careful study, large experience and excellent judgment. Failing these prerequisites, large sums of money may be utterly wasted, for such equipments are very costly at best.

In no direction will be found larger differences between the costs and the results of operation of, on the one hand, well selected and properly employed outfits and, on the other hand, badly chosen and inefficiently utilized tools and machinery.

An Outfit for Experimental Engineering, both for instruction and for research, constitutes in the larger and more advanced schools the most important and fruitful of all portions of the equipment. This is a kind of work which, as a matter of course, can be profitably undertaken only after the student has acquired a good knowledge of the higher mathematics, including a strong course in applied mechanics, and after he has obtained a fair knowledge of the subjects which are to be made the objects of investigation. In the great engineering schools, the undergraduates are given a course of laboratory instruction in this experimental engineering work; while the labors of investigation and of scientific or professional research are only undertaken, as a rule, by men of maturity, graduates of the schools, well prepared by education and professional experience, as well as by that natural aptitude which is no less essential for carrying on this highest and most exacting of all scientific work. In my own experience, I have, however, often seen admirable and permanently valuable work performed, with exceedingly fruitful result, by young men who had this talent, and who had made themselves familiar with the art and with the state of its science, in departments of knowledge and of engineering work in which research involved no very serious intricacy of mathematical investigation or extensive scientific knowledge; while some of the very best investigations of a higher sort that I have ever known have been the work of still-young men, making a specialty of the subject investigated.

The effect of such a training, in this kind of application of the principles already learned in the class room, upon a bright student is, however, remarkable, whatever the nature of the course in which he engages. It awakens an interest in science and in its useful applications such as no other method of instruction can produce. It gives him new powers, new interests, new and substantial knowledge, knowledge acquired at the finger ends as well as by the exercise of the mental faculties, and thus more real and more permanent than any "learning of the schools," purely, can ever be.

The process of preparation of the equipment in this department should, I take it, be similar to that already described in connection with the subject of tool equipment. That is to say, the beginning should be made with the simpler and less costly apparatus required to illustrate the elementary, the introductory, portion of the course; and this selection of the material should be made in such manner as to fit to each section of the course of instruction just that apparatus which will best, and in the simplest and least expensive way, exhibit its principles or its methods. Thus the instruction may be made progressively more and more complete and valuable, without in any manner neglecting the duty of thoroughness of instruction. The quantity of apparatus required will be determined by the length and the character of the work undertaken. In many schools, only a very elementary course can be given, and the apparatus will be small in quantity and inexpensive. In the more advanced schools, large sums can be profitably expended in the procurement of apparatus which will suitably illustrate a course of instruction involving the application of the most advanced courses of instruction in all the physical sciences. These courses, in experimental work, commonly begin with instruction in the use of instruments capable of employment in the illustration of facts and principles relating to the strength of materials and other lines of work demanding the practical employment of principles and methods taught the sophomore or junior classes of the school or college, and they are gradually extended as it is found practicable, until they include a fairly complete provision for the illustration of every scientific application of the class-room work, and in all departments of engineering, even; usually, now, including those of thermodynamics and the fundamental work in steam engineering.

When the undergraduates have been thus taken care of, to the limit of the collateral courses of undergraduate instruction, provision may be undertaken for graduate and original work in research. The apparatus here called for is often of entirely a different description from that previously demanded for the undergraduate department in experimental engineering. While the use of the same apparatus is to a very large extent practicable, and wherever practicable, desirable, it will be found that the special apparatus of research is often, if not usually, necessarily constructed especially for the purposes of the investigation contemplated. It is special and therefore, as a rule, comparatively costly. It is used only for its one primary purpose very generally, and, therefore, may have only historical value when, finally, the work being completed, it is set aside. Colleges must evidently, for these reasons, go into such work with the greatest caution, and it will often be found impracticable to undertake important and desirable lines of research in consequence of their costly requirements in apparatus, and even, often, for labor.

In such cases special contributions must be depended upon from those among wealthy and patriotic and interested men outside the college who are, in many cases, glad to do what money can toward the prosecution of such investigations. Care should be at all times taken to see that whatever apparatus is procured for special research is so made, if practicable, as to serve the general purpose of the laboratory after its special work has been completed. This, the highest and most fruitful of all work in engineering schools, will prove too costly to be undertaken by any colleges but the wealthy few, and only with great caution and conservatism by them; but it is the line in which the engineering schools are to-day most rapidly developing and in which they are doing most for the profession and for the nation. The application of scientific methods to the solution of the great engineering problems looming up before the profession promises to do more for the world than has any other systematic professional work ever yet undertaken.

The schools are coming to be wellsprings of professional and general knowledge of fact and phenomena such as the world never before saw or dreamed of. That school which can find the men to use, and the apparatus to be used, in the acquirement of new facts and data, and in the revelation of new processes of nature and their useful applications for the promotion of the work of the world, will do most for all.

Fortunately it is the first part of this line of work that is most essential. The cost of the first installments of the equipment need not be great, and, with time, every school in which the ambition and acquirements of its faculty are commensurate with its opportunities, will gradually and steadily increase the outfit until it will, in time, become prolific of large additions to human knowledge. A small equipment of home-made apparatus in the hands of one master mind, too, will always prove more productive of real and valuable results than the largest and most ambitious of equipments in the hands of ever so many men of ordinary or mediocre talent.

Five thousand dollars will give a good start for a laboratory of instruction in experimental engineering; hundreds of thousands in good hands may be profitably employed for the good of the profession and of the nation. Hundreds of thousands, perhaps millions, of dollars, thanks to the intelligent liberality of the wealthy citizens of our country, are going into this direction of elevation of our technical schools and their work, and with more than commensurate advantage to the country. *Upon such thorough education of our engineers depends very largely the future progress of the nation.*

PHOSPHORESCENCE AND "LUMINOUS PAINTS."

By HENRY WURTZ, Ph.D.

MOST readers will remember the interest which was aroused some years ago in the subject of "luminous paints," so called, which has now apparently died out altogether.

But: "Tempora mutantur, et nos mutamur in illis." Taking a slight liberty with this quotation, we may suggestively translate it as follows: The times are changed and we *ought to* change with them. A discussion of this subject will serve to introduce one or two practical suggestions which may perhaps possess elements of novelty as well as of interest in the present stage of progress of events.

Phosphorescence is a word of very broad application, applied usually to all cases in which light is emitted with little or no heat. Such cases occur in all the three kingdoms of nature, animal, vegetable, and mineral. We get the term from *phosphorus*, but not in the sense conveyed to us now by this word, which now means for us one of the most important elements of matter. In fact, the word phosphorus, signifying *light bearer*, is at least sixty-seven years older than our knowledge of the element phosphorus. The latter was first discovered by Brandt, a chemist of Hamburg, in 1669, while the name phosphorus had then already been applied since 1602 to a material known as the Bologna or Bononian phosphorus, the first of the "luminous paints." This is stated to have been discovered and prepared, as a world's wonder, by a *shoemaker* of Bologna, from a mineral found on Mt. Paterno, near that town. This mineral, called also in those times *Lapis Bononiensis*, Bolognian or Bononian spar, etc., is now known to be common heavy spar, barite, or barium sulphate, whose true composition was not discovered till 172 years later, in 1774, by Scheele.

Another curious circumstance is that the light from what we call phosphorus is not true phosphorescence at all, nor, still more remarkably, does this light come directly from the phosphorus. It is not phosphorescence, because it is accompanied by quite appreciable heat, and is caused by slow combustion. The seat of this combustion and of the light is not the surface of the phosphorus itself, but in the surrounding air, as inspection will show. It proceeds from the vapor of the phosphorus, undergoing slow combustion. Phosphorus, like camphor and naphthalene, evaporates at the ordinary temperature, and in an exhausted tube, will condense to beautiful transparent crystals, of adamantine luster, on the interior of the glass.

The term phosphorescence would best be applied only to cases in which no heat is appreciably evolved, and no oxygen appreciably absorbed. This would probably exclude luminiferous animals, but not luminiferous plants. The "luminous paint" phenomena belong to what are called "phosphorescences by insolation or irradiation," giving out light in the dark after exposure to sunshine or daylight, or, as has been shown, to the light of burning magnesium, and doubtless also to that of the electric arc (though no actual record of this last has been encountered). Balfour Stewart (*Lessons in Elementary Physics*) classes these irradiation phosphorescences with fluorescences (that is, with the blue, green, and other colored reflections observed at certain angles from petroleum, quinine solutions, etc.), and says: "Professor Stokes has successfully explained these two phenomena. It appears that when certain rays of light fall upon phosphorescent or fluorescent substances, a change is caused, and the rays are transmuted into others, always of lower refrangibility. It also appears that this is more particularly the case with chemical rays, or those rays of great refrangibility beyond the visible spectrum," etc. Further on: "The only difference between phosphorescence and fluorescence is one of duration; in the former the effect continues for some time, while in the latter it vanishes as soon as the exciting source of light is withdrawn."

This appears to be one of those explanations which do not explain anything. Nothing is here stated but facts, which Stokes deserves honor for having been the first to unravel; but probably he himself would be the last to claim that he had presented any *explanation* of any of these facts. Above all, the classifying of the two kinds of phenomena together appears altogether irrational. The difference of *duration*, which is admitted, puts them apart almost *toto caelo*, the width of the sky. No permanent effect is produced on a fluorescent body, so far as has been shown, but it is clear that the light has produced in the phosphorescent body a profound atomic or molecular change, and disturbance of equilibrium, a condition of potential energy which requires sometimes a number of hours in the dark to destroy. The phenomenon much more resembles a photographic transformation than a fluorescent phenomenon; but is much more mysterious than either of these. It may with strong reason be asserted that the "change" which "is caused" in the case of fluorescence is simply a change in the quality of the light reflected or refracted (as with a prism or a polarizer), such change being produced by the fluorescent body; whereas in phosphorescence there is plainly a change also in the phosphorescent body itself, produced by the light.

There are other kinds of phosphorescence; as that produced in some minerals simply by heating them to points below incandescence; phosphorescence produced by impact, and by crushing certain bodies, organic and inorganic; quartz and lump sugar being two cases. Also phosphorescences appearing during decay and putrefaction of both animal and vegetable bodies and formerly supposed to be results of such decay. Hence the ancient superstition regarding "corpse lights," will-o'-the-wisps, and so on. It is now well known, however, that these lights are products of life and not of death—that they are phosphorescences of living bacteria, or microfungoids. The processes of putrefaction and decay are now regarded as processes of bacterian life. Hence it is that corpses do not putrefy, but mummify, at elevations too high for the growth of these microfungoids, and sometimes in dry, deep underground caves, from which their germs are absent, also when their germination is prevented by embalming. These cases and others that might be mentioned are of secondary importance to us now. The cases of phosphorescence by irradiation are those of present interest. Among the most powerful of these are many diamonds; other diamonds, however, being destitute altogether of this property. The Germans call these substances "light-magnets." It has been pointed out that none of them are black, all being white or light in color. For making the original Bologna or Bononian phosphorus, one prescription is as follows:

Mix powdered heavy spar to a dough with mucilage of gum tragacanth, imbed it in crushed charcoal, and heat in a strong fire for an hour. Inclose while still hot in glass vessels. The heavy spar must contain no iron, but an addition of 3 or 4 per cent. of magnesia improves it. Another chemist, Osann, reduced the heavy spar by heating in hydrogen. Daguerre pulverized mineral barite in a mortar (which must not be of metal) and filled with it a large marrow bone freed from fat, closed it with a lute, inserted it in an iron cylinder coated with fireclay, and heated it in a furnace for at least three hours. The bone must become white. If gray, the heat has been insufficient; the phosphorus should be white, or pale yellow. If heated again in other marrow bones once or twice more, its light becomes brighter.

Other authorities state as follows: Bononian phosphorus is best prepared by heating 5 parts of precipitated barium sulphate with 1 part charcoal powder over gas for 30 minutes, then igniting more strongly over a gas blowpipe for 10 minutes. Put into glass tubes while hot. The phosphorescence here, from both sunshine and magnesium light, is bright orange color. Celestine (strontium sulphate) treated likewise gives a faint yellowish green light. But the latter, when heated in hydrogen gas, emits after irradiation a green, blue, violet or red light. Strontium carbonate heated with sulphur yields a blue or emerald green phosphorescence. Magnesia improves the light of the strontium phosphorus.

Canton's Phosphorus (sulphide of calcium).—Marggraf first observed in 1750 that calcium sulphide became phosphorescent by insolation. Canton prepared it from oyster shells in 1768, and his name became attached to it. He heated together 3 lb. of burnt oyster shells, with 1 lb. of sulphur, ground together, for one hour in a strong fire. Grotthus made it also by first igniting whole oyster shells for half an hour, then interstratifying them with sulphur powder in a crucible, with their inner surfaces downward, and heated again for an hour. He stated that the whole shell thus treated yielded a brighter light than when powdered. Pure lime gave him a much weaker light. He attributed these results to the small amount of magnesia present in the shells, which is in accordance with other authorities.

Dessaignes recommends ignition of gypsum (calcium sulphate) with flour.

Osann, Wach, and others experimented much by adding to the oyster shells, etc., antimony, arsenic, zinc, tin and mercury sulphides, with variable results.

The above methods are given in some detail, as anybody may repeat them, vary them, and very likely improve upon them.

The special interest which the writer believes they have now is in connection with the great and increasing coal mining interest of this country. The idea has been long in his mind that this phosphorescence by irradiation, derived from sunlight when possible, and from arc lights or burning magnesium ribbon, in the absence of sunshine, should be used for lighting fiery mines, thus rendering impossible in many cases the frightful catastrophes, of which we have had far too many. Endless bands of some suitable material, coated with one of these phosphorescent preparations, could be made to pass continually through the shafts and galleries of the mine, wherever work was going on. At some point outside the mine altogether these bands would pass continuously through a chamber containing arc or magnesium lights, in close proximity thereto. Many mines—the number rapidly increasing—already have the electric machinery for producing such arc lights. In all cases the magnesium light—which is now by no means too expensive to render this plan impracticable—could be used. Sunlight, when available, could be concentrated on the moving bands—a remark which applies equally to the electric and magnesium lights. With such concentration the band could be moved more rapidly and could be made to reach the remotest depths of the mine before appreciably losing its brightness.

There has just come under the eye of the writer, while writing these lines, an item which appears to be going the rounds of the scientific journals, relating to recent experiments on phosphorescent sulphides, by a "Mr. Jacksh, of Trieste, Moravia" (Trebitsch? Trieste is in Istria, on the Adriatic), in which he states that calcium sulphide, treated at a red heat with a small quantity of a salt of bismuth, gives a "violet light, and retains its luminous quality for nearly forty hours after an exposure of only a few seconds. Here is therefore an additional line of experiment in this direction. He appears to have obtained poor results with barium, strontium, and zinc sulphides. There are, however, many conflicting statements regarding these different preparations, and to obtain the best results will, doubtless, require much precision in the preparation and admixture of the materials and in the application of the heat. The materials are cheap, and if liable to become inactive in time, can be readily renewed.*

* The application of this device of the endless self-luminous band is not limited to mines. All buildings, warehouses, etc., in which inflammable or explosive materials are stored, or handled, or manufactured, such materials as cotton, textiles, spirits, oils or naphthas, turpentines or varnishes, gunpowder, etc., could be rendered free from risk by this plan. Even a powder mill or a dynamite factory could be lighted in this way with perfect safety, and work carried on therein at night. A whole block of buildings could be lighted by one moving band, if susceptible of retaining its charge of radiant light for two or three hours.

VEGETATION IN AN ATMOSPHERE DEVOID OF OXYGEN, AND CONSIDERATIONS ON THE DAWN OF ANIMAL LIFE.

By Dr. T. L. PHIPSON, F.C.S., Graduate of the Faculties of Science and Medicine of the University of Brussels, Member of the Chemical Society of Paris, etc.

IN various papers published in the *Chemical News* during the present year, I have endeavored to show that in the earliest ages of the earth, when life first made its appearance, plants (*anaerobies*) must have been formed before animals (*aerobies*), as the presence of unoxidized substances in the primitive rocks proves that free oxygen was absent from the primitive atmosphere. The experiment on vegetation in hydrogen, which I published not long since (*Chem. News*, vol. lxvii., p. 303), shows that free hydrogen could not have existed in the primitive atmosphere any more than it can exist for any length of time in the atmospheric air of our days without becoming water.

On account of its feeble affinities, nitrogen alone could have formed the atmosphere in the earliest ages of our planet's history; and, previous to the advent of life, this primitive atmosphere was charged with carbonic acid and vapor by volcanic action, such as we see manifested to a considerable extent at the present time.

Hence the earlier vegetation of the globe developed in an atmosphere devoid of free oxygen, consisting of nitrogen, carbonic acid, and vapor, and *the whole of the oxygen now present in the earth's atmosphere is due to vegetation* extending over immense periods of time.

As the ancient plants were evidently anaerobic, it was interesting to ascertain whether the plants of the present time were essentially of the same nature, and my experiments have shown me that they are; also that they must have preceded animal life—the latter resulting from the gradual transformation of anaerobic cells into aerobic cells, *as a consequence of the changing conditions;* that is, the oxygen constantly poured into the air by vegetation.

At what precise geological period oxygen became present in sufficient quantity to allow of animal life might appear an interesting problem for the geologist, but *no such period will ever be determined*, because the change must have been very gradual; and the study of the lower forms of vegetable and animal life shows us that there is no hard and fast line between the two kingdoms. There is no such thing to be discovered as "the first vestiges of animal life." As the oxygen evolved from the anaerobic cells became gradually a greater factor in the composition of the air, these cells had to accustom themselves to it, until some became aerobic, and by their vital functions actually supplied carbonic acid to the air instead of oxygen.

In addition to the experimental notes I have already published to demonstrate the truth of these considerations, I may call attention to one experiment made with *Convolvulus arvensis* (a plant I have often used for this purpose) vegetating in an atmosphere devoid of free oxygen; while two other plants of the same species were growing alongside the apparatus in ordinary atmospheric air. It will be seen that the plants of the present day are anaerobic, like those of the older periods, and that free oxygen in the air is not essential for their existence.

This experiment with *C. arvensis* vegetating in what may be termed a "primitive atmosphere" is typical of what occurs with all the phanerogamic plants mentioned in my previous papers, and with all the green *Algæ*, such as *Protococcus pluvialis* and the minute *Microcystis*, or "green matter of Priestley," that develops in spring water exposed for some weeks to the light.

The nitrogen in my former experiments was obtained from pure sulphate of ammonia, but more recently I have got it by the action of potash and pyrogallol on atmospheric air. It will be seen, however, by what follows, that *the same volume of nitrogen may be used over and over again*, as it undergoes no alteration in volume or properties except those due to the oscillations of temperature and pressure. The apparatus consists simply of a graduated tube, wide enough to admit the plant easily, standing over water containing minute quantities of all the substances known (or supposed) to be useful to vegetation, and kept supplied with carbonic acid. Alongside of the graduated tube stands another smaller tube full of water; into this carbonic acid is introduced, at first once a day; it displaces the water, but in the course of twenty-four hours or so, the water has absorbed this gas, and the tube is again full of water. Carbonic acid is again passed into it the next day, and the water displaced, saturated with carbonic acid, thus finds its way to the roots of the plant. In this manner the water of the basin in which stand the two tubes is kept supplied with a good quantity of carbonic acid. The whole is exposed to a constant northern light, such as is used by artists, which I have found preferable to a southern aspect or to the direct rays of the sun; the temperature of the room has varied from 15° to 32° C. One-half of the water in the little basin is covered to procure darkness for the roots, and a certain quantity of carbonic acid is also let into the graduated tube from time to time.

In this primitive atmosphere of nitrogen, carbonic acid and watery vapor, vegetation is tolerably prosperous, in spite of the confined condition of the air. The carbonic acid is absorbed and replaced by free oxygen, so that after a certain lapse of time the gas in the graduated tube approaches the composition of atmospheric air and can even be made richer than the latter in oxygen. I have already shown that in pure carbonic acid a plant does not prosper long, but with a basis of nitrogen and vapor of water it will prosper with a large amount of carbonic acid for a considerable time, and will transform this carbonic acid into oxygen, volume for volume, until there is more oxygen in the gas than in common air.

First, 75 c. c. of pure nitrogen (reduced to 0° C. and 30 inches barometer) is introduced, and the plant being put in makes the whole 109 c. c. Then a certain amount of carbonic acid is let in, and the volume of gas oscillates during the experiment from 102 to 127 or 130 c. c., according to the temperature and pressure, and the quantity of carbonic acid above the water at the time of observation.

The little plant was introduced on July 25, its height being then 30 divisions of the tube. On the 26th it had grown to 37 divisions; on the 28th, to 44 divisions; on the 29th to 48; and on the 30th, to 51 divisions, when it began to curve. On July 31, it had formed a new leaf and was curving, occupying 52 divisions. On August 1, it had curved considerably, as all plants of the *Convolvulus* genus do, and measured only 50 divisions in height; but on the second it had shot up again to 64 divisions. It appeared very healthy. On August 3 it attained to 68 divisions. On the 5th there were new leaves formed, and the plant measured 70 divisions. During August 6, 7, 8 and 9 the plant was healthy and two more leaves had formed. The water being well supplied with carbonic acid, and a little introduced into the graduated tube, I left the experiment till September 18. On September 18 it had grown to 90 divisions, and by the 30th of the month to 94—nearly to the top of the graduated tube.

On October 2, it began to turn yellow, as did the two plants of the same species growing in the water outside the apparatus, as "witnesses." They all put on their autumnal tints at the same time, and were all dead by October 30.

The gas in the graduated tube (reduced to 0° C. and 30 inches barometer) measured 95 c. c. It was analyzed on the 30th, and gave exactly:

Nitrogen	75
Carbonic acid	none
Oxygen	20
Total	95 c. c.

In the course of three months and seven days, or ninety-eight days, the plant had grown from 30 to 94 divisions, not counting the curve natural to the *convolvulus*, and had converted all the carbonic acid into oxygen, leaving the nitrogen exactly as it was at the commencement of the experiment. At the end of these fourteen weeks, the atmosphere of the graduated tube was thus found to be *richer in oxygen than ordinary atmospheric air*, which shows what would happen to the earth's atmosphere if there were an excessive supply of carbonic acid and vegetation did not deteriorate: *the oxygen of the air, due to plant life alone, would increase year by year.*

In the present state of things there is a kind of equilibrium *apparent* (not real), as during the last fifty or sixty years no excess of oxygen has been detected by analysis of the air. But what are fifty or sixty years compared to the thousands of centuries by which Nature counts her periods?—*Chemical News.*

PERFUME OF THE VIOLET.—F. Tiemann and P. Kruger have endeavored during ten years to isolate the chemical principle to which the odor of fresh flowers of the violet and of orris rhizome is due. They now state that the odorous principle of orris is a ketone, $C_{13}H_{20}O$, which they name *irone.* It is an oil, freely soluble in alcohol, ether, chloroform, etc., and boils at 144°, under a pressure of 16 mm. Its specific weight is 0·939, and index of refraction n_d = 1·50113. It is dextrorotatory, forms a crystalline oxime melting at 121·5°, and is transformed into a hydrocarbon, *irene*, $C_{13}H_{18}$, when acted upon by hydriodic acid. An isomeric ketone, *ionone*, $C_{13}H_{20}O$, having also a violet odor, can be obtained from citral. This body distills at 126°–128°, has a specific weight of 0·9351, index of refraction n_d = 1·507, and may be transformed into the hydrocarbon *ionene*, $C_{13}H_{18}$. The isomeric hydrocarbons, irene and ionene, yield on oxidation an identical product, ioniregene-tricarboxylic acid, $C_{12}H_{12}O_6$.—*Comp. Rend.*

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